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ART. XLIV.—*On the Action of Frost in the arrangement of superficial earthy material;* by Professor W. C. KERR.

To a foreign geologist, entering the Middle and South Atlantic States for the first time, a hundred miles or more from the coast, the most striking and novel feature of the geology is the great depth of earth which almost everywhere mantles and conceals the rocks. This is readily discovered to be, for the most part, merely the result of the decomposition *in situ* of the exposed edges of the underlying strata. The vertical and highly inclined bedding lines of these strata,—Archæan schists, gneisses and slates,—are distinctly traceable by the eye through this superficial earth-covering, and are seen to pass by insensible gradations into the undecayed rock beneath. Its depth varies from a few feet to twenty or thirty, and sometimes twice that and more, being usually greatest on the slopes of the hills.

So much is obvious, to the most casual observation, in the railroad cuts, and in the gullies by the roadside. But a more minute and systematic study of these superficial earths soon shows that the matter is not nearly so simple and easily explicable. It very soon becomes evident to the careful observer that there are in fact three kinds of earthy layers, each having a different structure and origin. Their usual color is brick-red to brown of various shades, from the oxidation of the iron-bearing minerals.

The banded structure of the original rocks, above referred to as characteristic, being marked by difference in color and composition, according to the varying lithological and chemical constitution of the underlying strata, does not reach the sur-

face, but fails at the depth of four or five to eight or ten feet or more, the materials above this being quite homogeneous.

This thin top layer is well nigh universal, and always recognizable. A little attention suffices to show that it owes its difference in structure and appearance to the penetration and the mechanical and chemical action of the roots of forest trees. The mechanical action of these roots has broken up and obliterated the lines of bedding and commingled the different materials, and their chemical action, living and in decay, has changed their composition and color, sometimes bleaching the whole mass in a degree which decreases with the depth, and not unfrequently in a very irregular manner, so that a section presents a pied surface,—red, of various shades, mingled with splotches of a gray, or pipe-clay color.

A second division of the superficial beds in question underlies (or replaces) the preceding, but is much less extensive, being found chiefly on the hill slopes and occasionally arching, in thinner mass, over the tops of flattish ridges and swells. It is found throughout the hill country and the mountain section of the State, being most conspicuous in the Piedmont, and passing, eastward, insensibly into the Quaternary deposits. The thickness varies from a few inches to twenty, thirty and even fifty feet, and the beds are very irregular in form. These deposits are best developed and may be most successfully studied in the gold gravels or placer beds of the State; but their structural features may be seen in the railroad cuts almost everywhere.

This division is, in general, readily distinguishable from the underlying mass, first, by a complete obliteration of the bedding lines and by a sharp line of separation, and secondly, (from both the other divisions) by a thorough commingling and a more or less obvious (if generally partial) rearrangement of its materials,—an obvious *tendency to restratification*, in an approximately horizontal direction. This generally consists merely in an aggregation of the coarser materials of the beds toward the bottom, or along certain horizontal lines.

This and other features of these beds will be best understood from a few diagrams. Figure 1 represents a section seen

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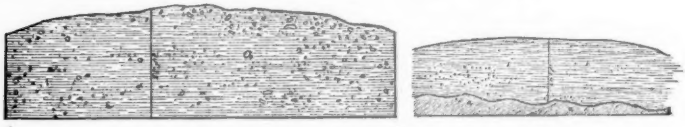

in a railroad cut near Henry Station, not far from the eastern base of the Blue Ridge in McDowell County. We have here

a mass of earth with fragments of rock, mostly quartz, of various sizes, in a nearly homogeneous accumulation, with scarcely a discernible arrangement. Figure 2 represents a similar deposit of much less depth, in a railroad cut at Cary, near Raleigh; and figure 3, one near Rockingham, in Richmond

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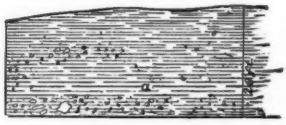

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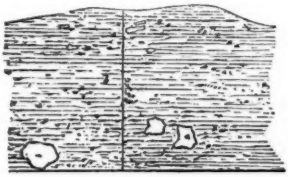

County, the last two near the margin of the Quaternary deposits. In figure 4, from the same locality as figure 1, we have an accumulation of coarser and more heterogeneous materials. In the three former cases, there was simply earth with small fragments of quartz; in the latter, besides quartz fragments and bowlders a yard in diameter, fragments, large and small, of gneiss and hornblende slate and other underlying rocks. In figure 5 the deposit is shown as capping the summit of a hill, a phenomenon of not uncommon occurrence in the Piedmont region: the section here shown is found near Old Fort, in the upper Catawba Valley. In this and in figure 6, two points are illustrated, viz: the partial arrangement of the materials, the accumulation of the larger fragments and pebbles toward the

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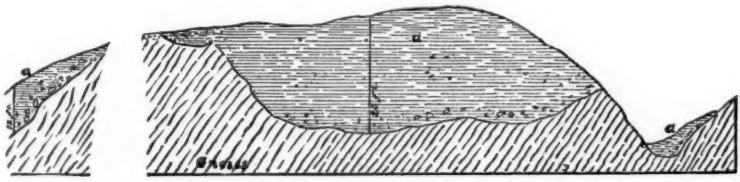

bottom of the beds, and along certain horizontal planes, and the complete independence of these deposits on the form of the surface on which they lie. They also illustrate another important point, viz: that the present topography of the surface is the result of *an extensive erosion, subsequent to the accumulation of these deposits*, so that the hills and valleys of the present and the subjacent topography have often changed places, and these present deposits are mere remnants of much

larger and wider accumulations which once filled up the valleys and mantled over the hills and obliterated the features of a former topography. This conclusion is abundantly attested by numerous observations.

Figure 7 brings out another common feature,—the occurrence of periods in the deposits, or of several deposits one upon another. This section is taken from a gold placer in Brindletown, Burke County, near Morganton, at the foot of a little mountain, called the Pilot, the lower slopes of which, next the valleys and streams, are covered with placers of varying depth, up to fifty feet. The same thing is shown in another placer mine on the same side of the mountain, a section of which is given in figure 8. The division between the successive beds at this point is not as sharp as represented in this diagram, although in many cases they are so. The lowest stratum (1) which lies on the decomposed gneiss and mica schist (the slate of the miners), is a four to five foot stratum of slightly rounded quartz fragments of an inch or two to six inches in diameter, the interstices filled with gravel and earth,

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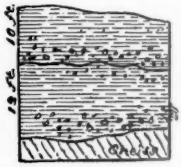

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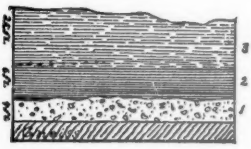

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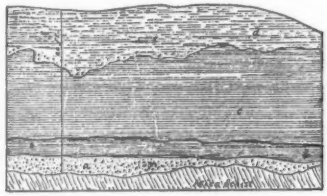

—a coarse half-compacted conglomerate, which gives place, upward, to a bed of gray, or ash-colored earthy clay (2), six or eight feet thick, above which lies twenty-five to thirty feet of red gravelly earth (3), with a few small scattered quartz fragments.

Figure 9 represents another similar deposit half a mile distant from the last, the section being taken, as were the last two, in the gold mines of Col. J. C. Mills, the last at the eastern base of the Pilot, and at a somewhat lower level. The two lower division lines, in this case also, are a little too sharp, the only distinct breach of continuity being found between the strata *c* and *d*: *a* and *b* shading into each other, somewhat abruptly, and so *b* into *c*. In this section *a* and *c* correspond to 1 and 2 of figure 8, *b* being an interpolation, and furnishing

the explanation of the bed 2. This interpolated bed is a peaty, black, gravelly soil, with blackened stems and bark of trees and fragments of wood and grass blades, roots and stems. The bleaching of bed 2, figure 8, and of *c*, figure 9, is evidently due to the solvent action of the humous acids from the old soils of the slopes from which this deposit came.

Figure 10 is a section in a railroad cut near Statesville in Iredell County, which shows two muck beds *a*, *a*, in contigu-

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ous depressions which have been buried deeply by earthy accumulations, which show only a slight tendency to stratification, in the apparent *settling* of the quartz fragments.

Now in none of the foregoing sections is there any indication of a proper stratification by the action of water. Indeed it is clear enough that the action of water is excluded by the most obvious features of these deposits. It is proper to say here, however, that there are deposits here and there, which do show traces of such stratification; and occasionally, in certain situations, deposits like those above described, in some parts of them, show slight and partial indications of water action. These, however, are exceptional, and constitute a class by themselves, and need not detain us here.

The diagrams above given represent the general character of hundreds of sections to be seen along any of our railroads. They offer no hint or suggestion as to the origin of these deposits, the cause or mode of their formation. The most frequent and conspicuous of these phenomena are seen, as stated above, in the Piedmont. The railroads of necessity follow the course of the river valleys, and the sections are consequently those of the lower ends of the jutting hills and spurs which slope down into the margins of the plains: that is, they are transverse sections of these ridges and slopes. It goes without saying, that the arrangement of the materials of these deposits, the *settling* of the heavier elements, can only have occurred in consequence of some sort and degree of movement of the mass. It is equally evident that such movement, whatever its cause, must have been in the direction of the slope of the surfaces on which they lie, that is, at right angles to the usual plane of section. And it is only by observing the relation of the arrangement or settling, to the situation on the slope, and by studying this arrangement at different

elevations along the line of movement that a clew to their origin could be had. The gold mines, at different elevations near the base of the Pilot, furnished the opportunity for such comparison. It was thus seen that the distribution of the materials of these deposits at their upper portions is represented by figures 1, 2 and 4; at a lower point by figures 3, 6, 7; and still lower by 8, 9. That is to say, a *longitudinal* section, down the slope, would be expressed by figure 11. Above, toward the left of the figure, the angular fragments of rock are distributed

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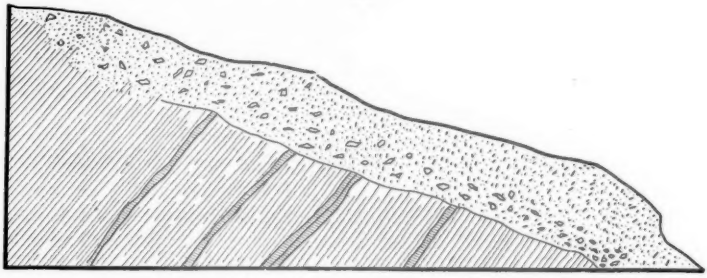

through the mass, but they are seen to descend, and to accumulate with the descent, toward the floor of the deposit and to become more rounded. It may be stated here that the coarse particles of gold in these placers are found with the pebbles,—gravel, and where these have accumulated at the bottom, only this part of the deposit is usually wrought, unless water is abundant; but at higher levels, where the gravel is scattered through the mass, the coarse gold is equally diffused.

The movement down hill then is evident, and the degree of arrangement or settling is proportioned to its amount. Of course the first suggestion that occurs, on this presentation of facts, will be that gravitation may have given rise to the motion. But this theory would not be entertained for a moment by one familiar with the actual sections. These deposits occupy the *lower slopes* of the hills, just where they meet the plains, the inclination varying from two or three to ten and rarely twelve degrees. This is obviously quite insufficient to give rise to any sensible movement from gravitation. Such movements of loose earth and stones do occur, but only on steep slopes of 40° and upward; and such accumulations are not uncommon at the foot of steep declivities; but these are distinguishable at a glance from the deposits in question. And further, instances are not unfrequent of the movement of these deposits on a dead level, and even *up hill*, over local obstructions or irregularities of surface.

The following diagrams illustrate these points, and show the grounds on which the theory adopted for the solution of the problem of the formation of these deposits rests.

Fig. 12 represents a section in a railroad cut near Morganton, which gave the first hint of the true theory of the origin of these beds; and fig. 13 is a similar section ten miles west of the former, near Muddy Creek bridge. In both these cases the vein (shown at *a*) is distinctly seen to be the source of the jointed, rhomboidal quartz fragments which are scattered along the floor of the deposit toward the right hand end of the diagram, a distance of one to several rods.

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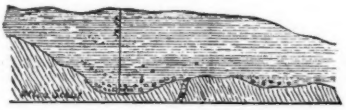

Fig. 14 represents the opposite side of the same railroad cut as fig. 12. In this the fragments are scattered right and left from the vein.

Fig. 15 is a similar section from a railroad cut in Richmond

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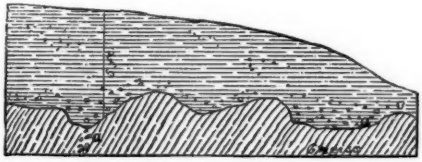

county, near the Peedee river. In this case a large quartz vein in a chloritic argillaceous slate has been broken down by the denudation which the rocks have undergone, and its fragments have been carried to the left and have settled part way through the moved mass, the upper portion of which has been removed by subsequent erosion.

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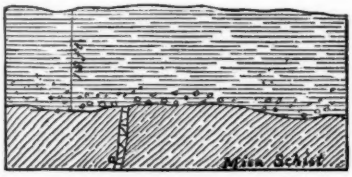

Fig. 16 represents the first stages of movement across a small vein. This is a quartz vein seen in section in a gold mine on the slopes of the South Mountains, near Brindletown. The thin-bedded, soft, decomposed mica schists are intersected by numerous small veins and seams of a granular (saccharoidal) quartz, varying from a usual thickness of one to three inches (occasionally four to six) down to a mere line. These thin

veins and seams are so numerous in places, and contain so much free and loose gold in the crevices and on the walls that

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it is profitable to sluice down the whole mass. The quartz is also rich enough for milling, yielding from ten to forty dollars to the ton. Other illustrations of these veins may be seen from the same mine in figs. 19 to 21.

It is clear, then, that these deposits were not accumulated by the action of water, nor by gravitation; and they present none of the features by which glacial deposits are usually recognized. No precisely parallel phenomena seem to have been observed elsewhere, or they are not recorded. And they remained an enigma to me for several years; and until such sections as shown in figs. 12 to 16 were discovered and studied. In these, and in those subsequently found in the gold placers, the character and amount of movement were clearly revealed.

The explanation which these facts have suggested, and which subsequent observation in this State and in other States has fully confirmed, is that the movement in question, to which the gradual settling of the heavier particles and fragments through the mass is due, *was produced by frost*, and that these deposits *are of glacial age*. As the earth is often frozen, in Canada and even in Vermont, during severe winters to a depth of eight or ten feet; and as in Labrador and other sub-arctic regions the frost of the present winters penetrates to a much greater depth, so, it is evident, that during the prevalence of the great ice sheet over the northern end of the continent, as far down as Pennsylvania, and the prevalence of an arctic climate in these middle latitudes, the earth was annually frozen to a depth equal to the maximum thickness of these deposits. The alternate freezing and thawing of the saturated mass of decayed rocks, constituting the pre-glacial surface, would of necessity produce just the movement and settling which are described above. That is, this freezing and thawing would give rise to precisely the same movements of the mass, and of the particles *inter se*, as are seen to occur in the true glacier, *differing only in amount*. In other words, these masses were *earth glaciers*, and these deposits may be denominated *frost drift*, as distinguished from proper glacial drift.

I do not see how these conclusions can be avoided. It seems evident that such phenomena must have occurred during the prevalence of cold of the intensity which an admitted arctic climate must have produced. And, if so, similar effects must be produced in arctic climates, and to some extent in the high latitudes of climates less intense, to-day. And, if so, too, similar phenomena may be expected to be found in regions farther north, produced during the retreat of the ice when these regions were successively subjected to the same degree of cold. Of course these effects would be visible only in exceptional localities, where the surface was not buried under glacial debris, and where the exposed rocks were capable of comparatively rapid disintegration. And, in fact, I have seen in Philadelphia and vicinity, phenomena which plainly come under this class. During the Centennial Exhibition, Market street was extended westward a square above Forty-fourth street, and a hill of some twenty feet was brought to grade in the process. Happening to pass during the excavation, I took a sketch of the exposed section, which is given in fig. 17. The

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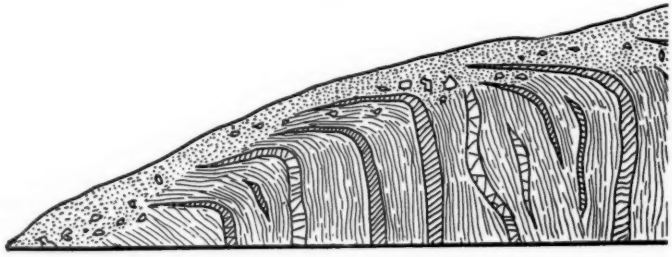

rock is gneiss and mica schist with hornblendic and chloritic strata, inclined at a high angle, and decomposed, for the most part, the entire depth of the cut, presenting a banded section of variously colored earths. The most striking and novel peculiarity of this section is shown in the sketch, viz: the gradual drawing out,—attenuation of these colored bands, as the parts of them in succession were moved down the slope. This section furnishes a new illustration of the character of the relative motion of the different parts of the mass.

As the thickness of the deposit at this point is not more than three to four feet, and there was no reason to suppose any recent or rapid denudation, the probability is strong that it is of recent (*present*) origin, the existing climate of Philadelphia being equal to the production of such effects. Fig. 18 represents a similar section in a drift of a mica mine in Yancey County, this State, near the base of the Black Mountain.

Among the inferences from the above conclusion, in the way of a corollary, is this important one, that the deep decomposition of the rocks of these latitudes has been effected entirely in post-glacial times, since the movement of these earth glaciers would sweep away every thing movable, down to the solid rock; and the frost was sufficient to carry the movement to the greatest depths of previous decomposition. And this conclusion is confirmed by two observations; first, that the force which was sufficient to remove the bowlders and rock fragments which often constitute the lower portion of these deposits—frequently of several tons weight, would abrade and remove every thing but the solid rock; and second, that the irregular form which the floor of these deposits often exhibits, as seen, for example, in fig. 13, corresponds to the unequal decomposition of the different strata of these very variable schistose rocks. This of course excludes any theory like that sometimes broached, which undertakes to account for this phenomenon, by invoking the action of a paleæval atmosphere surcharged with carbonic acid.

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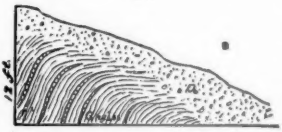

As already stated incidentally, the gold gravels, or placers, of this State, of which there are several hundred square miles, belong to this class of frost drifts. The miners in these deposits usually wash only the lower stratum of "gravel," or pebbles, which lies against the bed rock, or *slate*, together with an inch or two of the surface of this slate on which the coarser gold particles are lodged. The gold and the quartz pebbles are derived, as above indicated, from thin veins and strings which penetrate the more thin-bedded mica schists. As these are disintegrated and broken down and moved, in the manner

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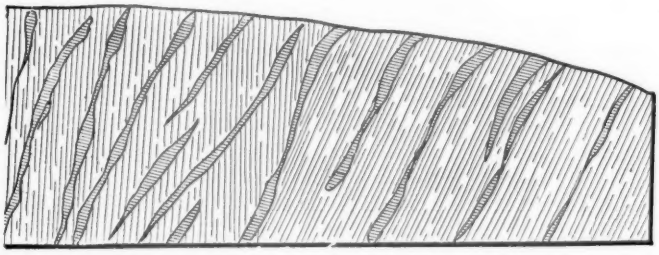

just described, or abraded and swept down by floods, these pebbles with the coarser gold are collected either in the manner described, or in the beds of the streams. Examples of

these veins are shown in fig. 19, which represents a common aspect of them in section, in the mines previously alluded to, in which the veins themselves and the including mass of decomposed rock are sluiced down and washed just like a placer. In fig. 20 a vertical section of 20 feet of a single vein of this description which is a thin sheet of quartz, of an inch and less in thickness, yet rich enough to have been followed to a depth of 20 and 30 feet for many rods. Fig. 21 represents the floor of another mine at the same locality, in which several such thin sheet-veins are wrought in one cut, the vein-matter being reduced to nothing at certain points, leaving a mere joint or fissure plane.

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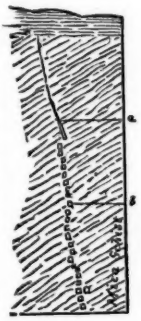

In fig. 22 the relation of the placers to the topography, and of both to the governing geological conditions, are exhibited. This diagram represents an ideal section southeast and northwest, transversely to the strike, across two of the richest and most noted gold valleys, separated by the Pilot, already familiar to us; these are the valleys of Silver Creek and Muddy Creek, known as Brindletown and Bracketttown. The Pilot and the ridge of the South Mountains (the left in the section), owe their existence to the harder and heavier bedded gneisses of which they are composed, while the valleys have been scooped out of the softer and thin-bedded mica schists and hydromicaceous rocks, which are also more abundantly veined. It is an old observation of the practical miners, that the gold deposits occur only on the east (and south) slopes of the mountains, while the opposite slopes are comparatively barren. The reason is obvious from an inspection of the diagram. The thicker bedded rocks have fewer veins, and the southeast slopes are the long ones, while those opposite are steep and short; and much the larger part of the abraded vein-bearing

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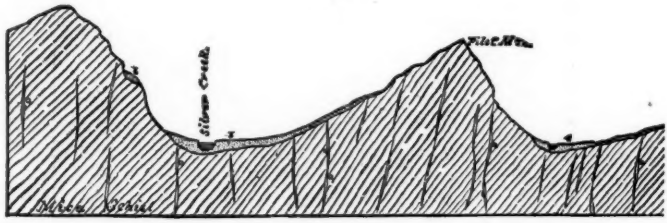

masses have been removed from the space above these long slopes.

It has already been stated that, as shown by the most obvious features of these deposits, they have been much more extensive than at present. In some cases, over considerable spaces, the deposit has been entirely removed by denudation, leaving only the floor covered with a layer of quartz pebbles and angular fragments, and the gold in the present soil within

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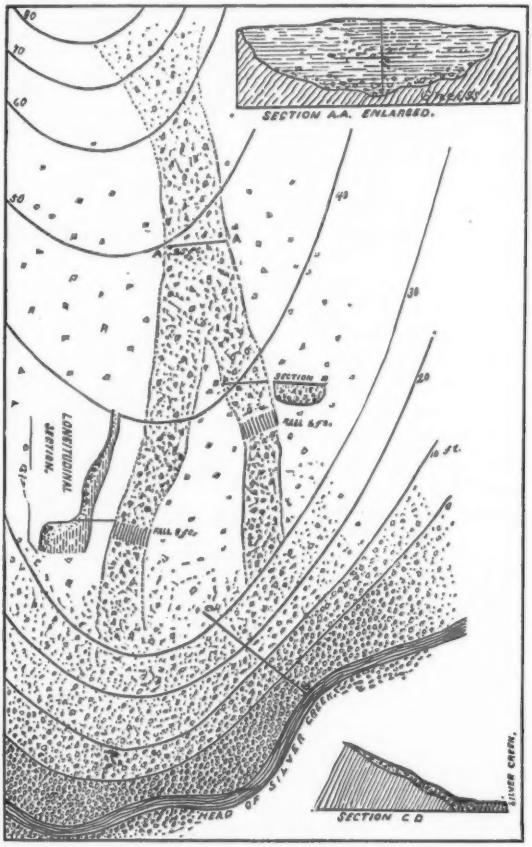


reach of the plowshare. Many of the richest gold washings of this state have been of this description, and farms, gardens, yards and the sites of houses have been sluiced away, and thousands of dollars per acre obtained from soils that had been

cultivated for generations, in ignorance of their mineral riches. Large tracts of this character, hundreds of acres in extent, are found in the locality already so often cited, the foot-slopes in the Pilot. The annexed diagram, figure 23, of a placer lying on a swell of land between those represented in figures 8 and 9, illustrates this point. The whole surface of this flat swell, which is nearly half a mile in width, is covered with the quartz fragments of the old bed gravel of an enveloping placer, which has been entirely abraded, leaving its quartz and gold in the soil, with the exception of the fantastic bifurcated strip seen in the figure, which evidently was preserved from abrasion by the furrow which the moving mass had plowed a little deeper along this line. The thickness of this strip increases from a few inches at the top to more than ten feet below the singular golden cascades represented on the two arms. Happening to be present while the last of this curious placer was worked out, I was able to catch and sketch its peculiar features. This small remnant of an extensive deposit preserves, as shown in the sections, at A—A for example, all the characteristics of such drifts,—a dense bed of coarse "gravel," of angular quartz fragments, at bottom, carrying most of the gold, and a thinner and more scattered layer in the middle, with visible gold particles, and the finer gold diffused through the whole ten feet of depth in sufficient richness to justify the excavation and washing of the entire mass.

The diagram (ideal as to its lower portion, and contracted longitudinally), also exhibits the character and origin of the gold deposits in the creek bottoms of the region, which were extremely rich when first wrought, thirty-five to forty years ago, yielding ten dollars a day to the hand, with the rudest apparatus and most unskillful labor. The gold of these creek gravels, as shown in the figure, was derived from the placers swept down from the adjacent slopes.

And it may be of sufficient interest to justify the repetition here of a fact to which I have recently called attention elsewhere, that these gravels are regularly worked over at intervals of eight to ten or twelve years, and at some of the localities, on Silver Creek, for instance, they have been re-worked profitably half a dozen times, only the coarse gold being obtained each time by the rude appliances and methods used. The point of interest is, that the fine and diffused and scale gold which escapes in these rough washings and sluicings, evidently undergoes a process of aggregation: a fact which was noted by Professor Lieber, state geologist of South Carolina, in his geological report of that State, published before the war, but which seems to have escaped due attention. This is readily accounted for by the considerations first, that gold is soluble in alkaline waters;

and second, that these drifts are largely the debris of half-decomposed feldspathic gneisses and schists, of which the feldspathic particles are undergoing kaolinization, liberating the alkaline salts, while the silica attacks such fragments of organic matter as happen to be present, subjecting whole trunks of trees of more than a foot in diameter, to complete silicification even while lying within a few feet of the surface, and facing the drusy rifts of the wood with perfectly terminated quartz crystals.

Raleigh, N. C., March 15, 1881.

ART. XLV.—*Dall's Observations on Arctic Ice, and the bearing of the facts on Glacial phenomena in Minnesota;* by N. H. WINCHELL.

MR. DALL'S observations on the existing perennial ice in northern Alaska are highly interesting and valuable* at this point in the history and progress of glacial theory. He describes the region about Eschscholtz Bay as made of gneissoid rock and volcanic breccia, but without attaining anywhere in the vicinity any greater height than three or four hundred feet above the sea. He also states that the formation of the surrounding country shows no high land or rocky hills suited for the production of a glacier. In this respect it is like the interior of North America, throughout the Western and Northwestern States where there is proof, now rarely questioned, of the former existence of vast fields of glacier ice; and it is highly probable that the field explored by Mr. Dall is an epitome, under peculiar and somewhat inexplicable circumstances of the vaster field which extended from the Rocky Mountains on the west to the Alleghanies on the east, during the latest epoch of continental ice, the only important exception being that over the Continent the southern termination of the ice sheet was everywhere invisible, and abutted nowhere (in the interior) on the ocean shore so as to reveal its existence. The surface covering of the ice was the surface of the country, and over many miles north from its actual termination, it supported a varied and even rank vegetation. Mr. Dall's observations on the "fossil glacier" extending west from Point Barrow and south as far as Kotzebue Sound, seem to prove that the northern slopes of Alaska are now glacier-covered; throughout the most of which distance the margin of the ice is but occasionally revealed by reason of the wave action on the overlying drift.

* This Journal, xx, p. 335 and xxi, p. 104.

In numerous places it seems that the ice is so far attenuated that the drift which it brings forward is the barrier against the ocean, and in other places the ice itself, underlying the drift, is brought into contact with the water of the Arctic Ocean. Without a just conception of the action of the vast continental glacier of glacial times, it is difficult to conceive of this ice in motion, and Mr. Dall believes it has no motion, adducing, however, only the unbroken condition of the mosses and peats on its surface to prove it. It is to be hoped that inland exploration may be made of the glacier at Elephant's Point, in order to ascertain if it is derived from some mountain source. It is almost certain, if our ideas of glacier ice be correct, to have such a source, though its connection unbroken from the coast to the mountains, may be hid from sight for miles, in the same manner as its east and west flanks are hid by the accumulations on its surface. It is also highly probable that it will be found to come in various ways into contact with running water, some of which will bring upon it the fine tough clay described by Mr. Dall, and in other places will precipitate upon it, in stronger current, the gravel and sand, and even some of the stones which he mentions as covering it near Point Barrow.

The facts reported by Mr. Dall throw great light on the manner of formation and deposit of the till, which has been the source of much difference of opinion among glacialists. Some have imagined a *moraine profonde, pushed out from the front margin of the ice-sheet* in its retreat, left as a continuous terminal moraine from north to south after the ice had entirely disappeared. Others contend that it *was not only deposited at the ice-foot but also was formed there.* However satisfactory these theories may be to those who understand them, it is true that to some they are wholly beyond comprehension, and seem to be mythical. Another theory asserts that the ice *died out gradually, and imperceptibly beneath its burden of clay and stone,* and that the till is not a terminal moraine, but instead a surface moraine (to employ a new term) resulting from the same causes, whatever they may be, which bring the drift on to the surface of the ice in northern Alaska and which so frequently hide the surface of the small glaciers that have been described in the Rocky Mountains.

These observations also throw light on the cause and manner of formation of kames. Kames are gravel-ridges, lying in till-covered countries, and occupying the lower portions. They are generally coincident in direction with the direction of the present surface drainage, and often on either side of a kame, which may be several miles in length, there is a swamp or low spot, parallel with the kame, while on the right and left, outside of this valley, the unbroken till spreads out indefinitely.

The gravel of which the kame consists is of the same material as the gravel and stones found in the till that adjoins it, and was undoubtedly brought there at the same time that the till was—but necessarily by some other agent. The kame also sometimes becomes broken up, and fades out, by becoming hummocky and clayey, into the till itself. Now on the supposition that the till before its deposit lay on the surface of the ice, it is plain that surface drainage gathering into small streams and even rivers, would produce deep channels or gorges in the ice-sheet. In the bottom of the stream would be gathered such gravel, stones and sand as the stream had not current enough to carry away. The warmth imparted to it by the water would cause it to sink deeper and deeper into the ice, and in many places to lie on the rocky floor itself, especially in the southerly portions of the gorge where the ice would be thinner. It is easy to see that on the entire withdrawal of the ice, such a kame would lie undisturbed, in its beautiful stratification, where the river produced it; while on either side would be, first, the comparatively low or swampy belt caused by the withdrawal, during the existence of the river, of the clay of the till, and the concentration of its stones and gravel in the bottom of the stream by the sloping sides of the gorge, and secondly, outside of this swampy belt, the unmodified till itself. On the supposition that the stream was sub-glacial, not only can the circumstances not be imagined in accord with the known operations of gravity and momentum; but, if once so formed, the subsequent movements of the ice would inevitably have destroyed the stratification of the kame, and mixed it with the till. On the supposition that the kame was formed by such streams outside the area of the ice, on their debouchure from it, such steep ridges can hardly be explained. Gravel and sand so deposited are spread out more like "alluvial fans," and probably such are the superficial gravels and sands over southern Ohio and Indiana, south of the ice-margin at the time of the last glacial epoch.

University of Minnesota, Feb. 5, 1881.

ART. XLVI.—*On the Projection of Lines of Equal Pressure in the United States, west of the Mississippi River;** by HENRY A. HAZEN.

THE Signal Service Bureau of the United States has published, since 1873, more than 9000 different weather maps, upon which are projected isobars and isotherms for the United States and Canada from a little west of the Mississippi River to the Atlantic. It has been found practically impossible to continue the isobars across the Rocky Mountain plateau to the Pacific, or over more than half the country. The late Chief Signal Officer in his annual reports for 1877, '78 and '79, has stated in substance, that the reduction of pressures, at elevations west of the Mississippi River is greatly to be desired.

The solution of this problem is an exceedingly complicated one for the following reasons:

1st. The elevations of stations are not accurately known. In order to eliminate this error, the method of "isabnormals" or "departures" has been proposed. This system may be briefly described as follows:

We may consider the actual mean pressure for a month or year, at any station, to represent an even flow of air, with a depth indicated by the pressure; if there were no "highs" or "lows," the pressure would remain constant. The algebraic difference between the mean pressure for a month or year and each observation, in other words, the "departure," would indicate if plus, the presence of a "high," if minus, of a "low," and if these "departures" should be plotted on a chart for a series of stations, we should have apparently an exact means of describing a "high" or "low."

This method is open to serious objections and in fact may give results directly contrary to the truth. If all stations were at sea-level the results would be approximately accurate, but it will be seen that this would not be the case at elevations. For example, in winter the atmosphere condensed by the cold sinks and the pressure at a high station diminishes, whereas at the same time at sea-level the pressure increases. Since the temperature is constantly rising and falling it would be impossible to compare "departures" at different altitudes with each other or with those at sea-level.

In Table I are found "departures" as computed from the actual observations and also from the same reduced to sea-level.

* The term *pressure* is used to denote atmospheric pressure. Nearly every daily paper in the country is publishing "Indications" in each issue. in which the expressions "barometer" and "temperature," are almost invariably used. There should be uniformity. Why may not "pressure" and "temperature" be used?

TABLE I.

Departures at North Platte, Neb., elevation 2838 feet, for the observation at 7.35 A. M. Washington time, during January, 1879.

Date.	Temp.	Pressure.				Departure.			
		Actual.	Sig. Serv. Reduction	La Place.	Hazen.	Actual.	S. S.	L.	H.
1	3°	27″·22	30″·08	30″·55	30″·42	9	18	21	15
2	−13	27·27	30·25	30·74	30·55	14	35	40	28
3	− 8	27·44	30·43	30·90	30·71	31	53	56	44
4	− 9	27·31	30·27	30·71	30·57	18	37	37	30
5	4	27·41	30·31	30·65	30·60	28	41	31	33
6	− 1	27·01	29·85	30·30	30·23	−12	− 5	− 4	− 4
7	25	27·03	29·70	30·15	30·12	−10	−20	−21	−15
8	1	27·26	30·14	30·54	30·45	13	24	20	18
9	0	26·98	29·81	30·30	30·19	−15	− 9	− 4	− 6
10	12	26·97	29·72	30·18	30·12	−16	−18	−16	−15
11	3	27·15	29·99	30·49	30·35	2	9	15	8
12	6	27·04	29·84	30·32	30·23	− 9	− 6	− 2	− 4
13	14	26·98	29·72	30·16	30·12	−15	−18	−18	−15
14	6	27·05	29·86	30·31	30·23	− 8	− 4	− 3	− 4
15	10	26·99	29·75	30·23	30·15	−14	−15	−11	−12
16	2	27·08	29·91	30·41	30·28	− 5	1	7	1
17	9	27·06	29·85	30·30	30·22	− 7	− 5	− 4	− 5
18	3	27·23	30·10	30·57	30·43	10	20	23	16
19	8	27·32	30·18	30·56	30·49	19	28	22	22
20	23	27·24	29·97	30·42	30·33	11	7	8	6
21	16	26·97	29·70	30·15	30·10	−16	−20	−19	−17
22	37	26·91	29·50	29·93	29·95	−22	−40	−41	−32
23	27	27·13	29·82	30·22	30·21	0	− 8	−12	− 6
24	36	26·92	29·51	29·94	29·96	−21	−39	−40	−31
25	37	27·31	29·98	30·33	30·34	18	8	− 1	7
26	35	26·65	29·20	29·59	29·69	−48	−70	−75	−58
27	30	26·91	29·54	30·00	29·97	−22	−36	−34	−30
28	26	27·08	29·77	30·20	30·16	− 5	−13	−14	−11
29	15	27·36	30·18	30·58	30·50	23	28	24	23
30	26	27·34	30·08	30·44	30·42	21	18	10	15
31	27	27·27	29·98	30·37	30·34	14	8	3	7
Mean		27·13	29·90	30·34	30·27				

A comparison of the "departures" shows a difference of ±0″·10 between columns 7 and 10, and a still greater difference between 7 and 8 or 9. This discrepancy would be much increased at greater altitudes. No satisfactory projections then can be made with this system.

Having given pressures and temperatures, we may obtain an approximate difference of elevation, of neighboring stations, by applying the formula of LaPlace. In order to obtain some idea of the accuracy of leveling with the barometer the difference of height of the following stations has been computed, see Table II.

TABLE II.

Month.	Difference of Elevation.				
	Mt. Wash'g'n, N. H., & Portland, Me., 6 ys' observations.	Pike's Peak, Col., & Dodge City, Ka., 4 ys' observations.	Dodge C., Ka., & Leavenw'h, Ka., 4 years' observations.	Pioche, Nev., & Visalia, Cal., 1 years' observations.	Boise C., Ida., & Umatilla, Oregon, 1 yrs' observations.
January	6264′	11331′	1665′	5648′	2301′
February	6268	11414	1670	5758	2302
March	6284	11452	1725	5797	2398
April	6242	11485	1718	5821	2485
May	6232	11525	1734	5852	2495
June	6233	11545	1734	5819	2540
July	6225	11567	1752	5867	2522
August	6215	11565	1752	5792	2530
September	6236	11535	1756	5800	2438
October	6249	11426	1722	5722	2381
November	6275	11382	1670	5702	2343
December	6259	11326	1667	5637	2342
Year	6256	11470	1716	5772	2424
Mean of 12 mo's	6248	11463	1714	5768	2424
Mean	6252	11466	1715	5770	2424
True diff. level	6240				

In column 2, Mt. Washington is in latitude 45° north, near the Atlantic coast and sixty miles west of Portland, which is 46′ above the sea. In column 3, Pike's Peak is in the interior in latitude 39° north and 300 miles west of Dodge City, which has an altitude of 2555′. In column 4, Leavenworth is 300 miles east of Dodge City and 840′ high. In column 5, Pioche in latitude 37°·5 north is 300 miles east of Visalia, the latter near the Pacific coast and 370′ high. In column 6, Boise City is in latitude 44° north and about 200 miles southeast from Umatilla, which is 375′ high.

The most noticeable fact is that while the computed elevations on the Atlantic coast gradually diminish from January to July, the opposite effect is observed on the Pacific. The computed difference of elevation between Mt. Washington and Portland is within 12′ of the truth. In the west many of the elevations are in doubt.

Table III gives approximate elevations of most of the stations west of the Mississippi River.

2d. It seems well nigh impossible to determine the law of variation of temperature at most of the high stations in the west. For abrupt elevations, such as Pike's Peak, the law may be fairly well known, but this is not the case in most instances. For example, the mean temperature at Denver, Col., is 49°·1, at Dodge City it is 53°·4 and at Leavenworth it is 53°·5. These temperatures reduced to sea level at the rate of 1° for each 300′ elevation are, 66°·7, 61°·9 and 66°·3 respectively. Again, we frequently find the temperatures ten to fif-

teen degrees lower at Dodge City than at Denver. At Salt Lake City, on the elevated plateau west of the Rocky Mountains, there is a still greater difficulty, as the temperature seems to run too high.

TABLE III.

Station.	Elevation.		Station.	Elevation.	
	Signal Service.	Barometric.		Signal Service.	Barometric.
Bismarck	1704′	1740′	Leavenworth	813	840
Boerne	1333?	1400	Los Angeles	320	380
Boise City	2877	2799	Mason	1800?	1610
Brackettville	1026?	1140	North Platte	2838	2838
Camp Grant	4823?	4900	Phoenix	1800?	1150
Campo	2500?	2500	Pioche	5779	6148
Cheyenne	6057	6093	Pike's Peak	14151	14021
Concho	1750?	1900	Prescott	5700?	5230
Deadwood		4600	Red Bluff	338	410
Denver	5269	5265	Sacramento	76	100
Dodge City	2486	2555	Salt Lake City	4362?	4365
Fort Buford		1970	St. Paul	796	825
Fort Craig	4622	4570	Santa Fé	6851	7020
Fort Davis	5203	4900	Silver City	6896	5920
Fort Gibson	511	541	Stockton	2000?	3100
Fort Keogh	2536?	2480	Umatilla	461	375
Fort McKavitt	2050?	2230	Virginia City	5480?	5830
Fort Sill	1100?	1198	Visalia	348	378
Fort Stevenson		1760	Winnemucca	4335	4390
Fredericksburg	1614?	1720	Yankton	1275	1210
LaMesilla		4050	Yuma	155?	240

3d. Even if elevations were known, there seems to be no formula of reduction which can be applied to the varying conditions of the temperature and movements of the atmosphere.

In order to obtain a satisfactory method of reduction, the following plan has been adopted, based upon the theory that the fluctuations of pressure are in part dependent upon the temperature at the base and summit of a mountain.

Arrange in a table a column for temperatures running from $-30°$ to $80°$ in a vertical line, and a horizontal row of pressures, limited by the minimum and maximum pressures at the elevated station under consideration.

Take now the difference of pressures at any observation at an upper and lower neighboring station and place it at the intersection of a line passing through the temperature corresponding to the mean temperature of the two stations at the time of the observation, with a vertical line passing through the figure representing the pressure at the elevated station at the same time. By taking a sufficient number of observations, made at all hours of the day, and during all the months of the year, we can construct a table which shall represent the proper reduction of all observations at the upper station.

Tables have been prepared on this system for Mt. Washington, N. H., reducing to sea-level by comparison with Portland, Me., also for nearly all the stations of the Signal Service, above 1000′ in hight, west of the Mississippi River; column 6, Table I, is taken from such a table. For elevations under 3000′ the U. S. Signal Service have adopted a formula of reduction which always gives results too small.

On referring to Table I, we see that during the month of January, 1879, in one instance the reduction in column 4 was 0″·49 less than in column 6, and in two cases the reductions in column 4 were 0″·50 less than in column 5.

In the Annual Report of the Chief Signal Officer for 1876, are published tables computed by Lieut. Dunwoody, for reducing pressures at an elevation not exceeding 7000′ to sea-level. Table IV gives a comparison of reductions by these tables with those by Guyot's tables and also Baily's.

TABLE IV.

Reduction of Mt. Washington to sea-level.

	Actual Difference bet. W. & P.	Bally.	Guyot.	Dunwoody.	Hazen.
Mean annual pressure Mt. W., 23″·626 Mean annual temp'ature Mt. W. & Port., 36°·2	6″·356	6″·316	6″·342	6″·314	6″·356
Pressure Mt. W., 23″·00 Mean temperature Mt. W. & Portland, 20°		6·406	6·429	6·424	6·55
Mean temperature Mt. W. & Portland, −2°°		7·142	7·167	7·165	7·13
Pressure Mt. W., 24″·00 Mean temperature Mt. W. & Portland, 60°		6·060	6·082	6·046	6·05
Mean temperature Mt. W. & Portland, 20°		6·685	6·708	6·675	6·61

In column 1 are given pressures on Mt. Washington and the mean temperature between Mt. Washington and Portland. In the remaining columns are found the reductions to sea-level, as computed from various formulæ and tables.

Baily's formula in column 3 has been adopted by Charles Carpmael, Superintendent of the Meteorological Service of Canada, who regards the tables of Dunwoody as unsatisfactory. It would seem that all the results are nearly correct when means are employed; when individual observations are considered, however, the discrepancies are more marked, each of the formulæ in different portions of its range giving the best results. On the whole the reductions by Guyot seem the best

and those by Dunwoody are next. These discrepancies are still greater in the case of reductions of pressures at such an altitude as Pike's Peak. This is shown clearly in Table V.

TABLE V.

Reduction of Pike's Peak to sea-level.

Temperature.	Guyot.			Hazen.		
	17″·6.	17″·7.	17″·8.	17″·6.	17″·7.	17″·8.
60°	11″·61	11″·67	11″·74	11″·94	11″·93	11″·92
50	11·92	11·99	12·06	12·11	12·10	12·09
40	12·26	12·33	12·40	12·27	12·26	12·25
30	12·62	12·69	12·76	12·43	12·42	12·41
20	13·00	13·07	13·14	12·59	12·58	12·57
10	13·38	13·46	13·54	12·76	12·75	12·74
0	13·81	13·89	13·97	12·93	12·92	12·91

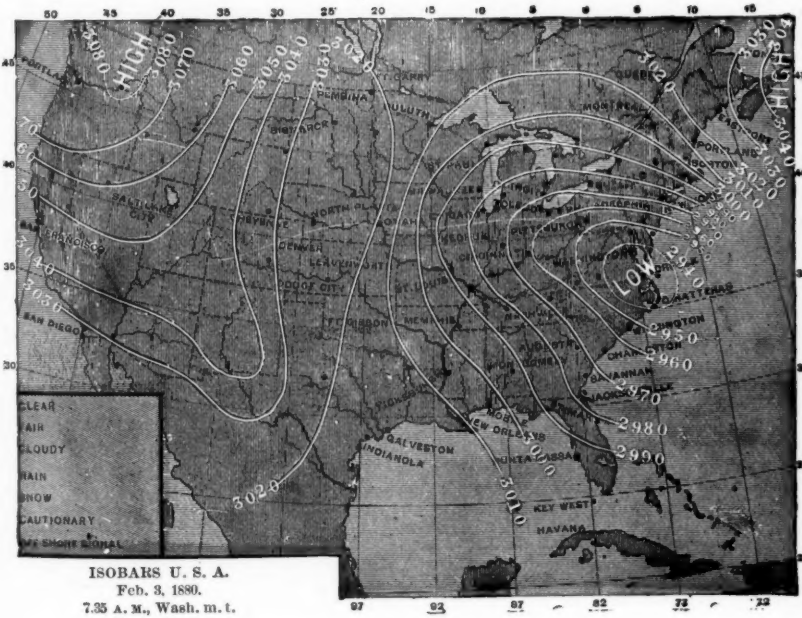
There seems to be a variation by these two methods of reduction of nearly one inch at 0° temperature. If it be objected that no account is taken of pressures at the lower station, and that comparisons made between stations 300 miles apart would differ from those near each other, also that the altitude of Pike's Peak is uncertain. It may be said that the extreme error due to these causes may reach 0″·6 at 0° temperature, and this would diminish with higher temperatures.

The most marked peculiarity in the two tables, however, is that *while the reduction by Guyot increases with an increase of pressure, the actual reduction diminishes.* This fact has been verified by reductions at a large number of stations.

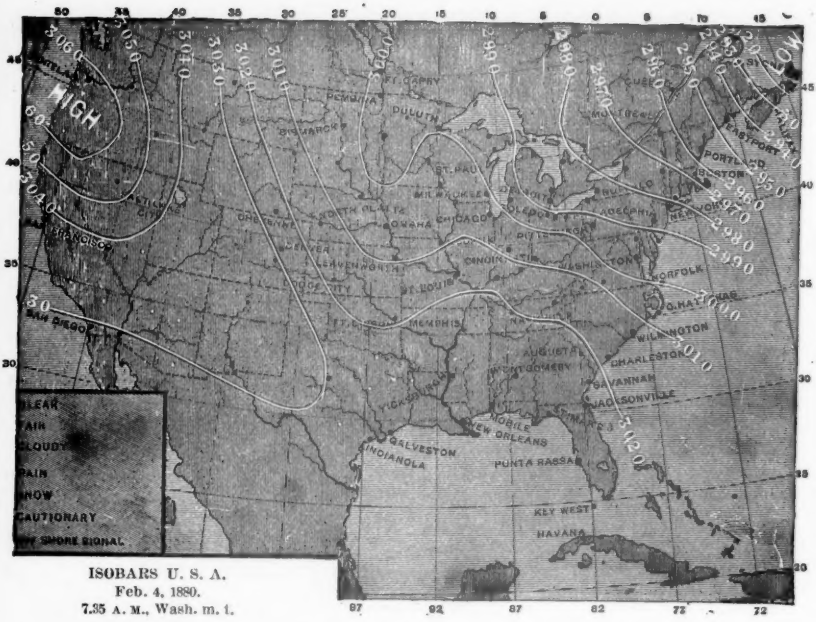
The method proposed then consists in this. All reductions of pressures at altitudes not exceeding 1000′ be made by the use of Guyot's formula. (Table VI, for facilitating this reduction is appended to this paper.) For all other stations reductions be made from tables specially prepared, from a comparison of observations at an elevated and at a lower neighboring station.

Plates are given, showing a projection of isobars over the whole of the United States, for the observation at 7.35 A. M. Washington time, from the 2d to the 7th of February, 1880. In making these reductions, the actual temperature at the station has been used for all except Pike's Peak, at the latter station the mean temperature between Pike's Peak and Dodge City has been employed. The isobars have been projected from the reductions at *all* the stations except Pike's Peak, Salt Lake City, Deadwood, Fort Buford and Fort Stevenson. Observations have not been published to a sufficient extent to give satisfactory tables for reduction in the last three cases; at Salt Lake City the temperatures are troublesome, and Pike's Peak is very high.

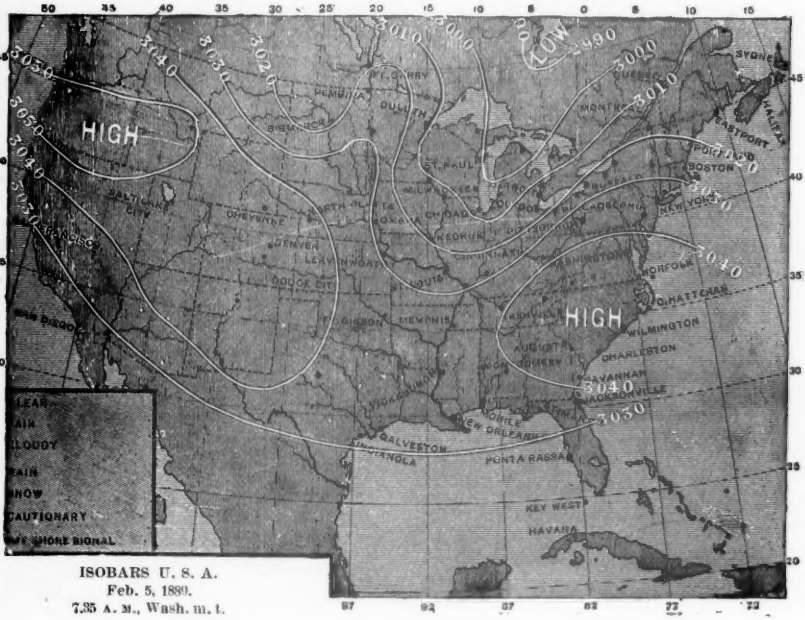
ISOBARS U. S. A.
Feb. 2, 1880.
7.35 A. M., Wash. m. t.



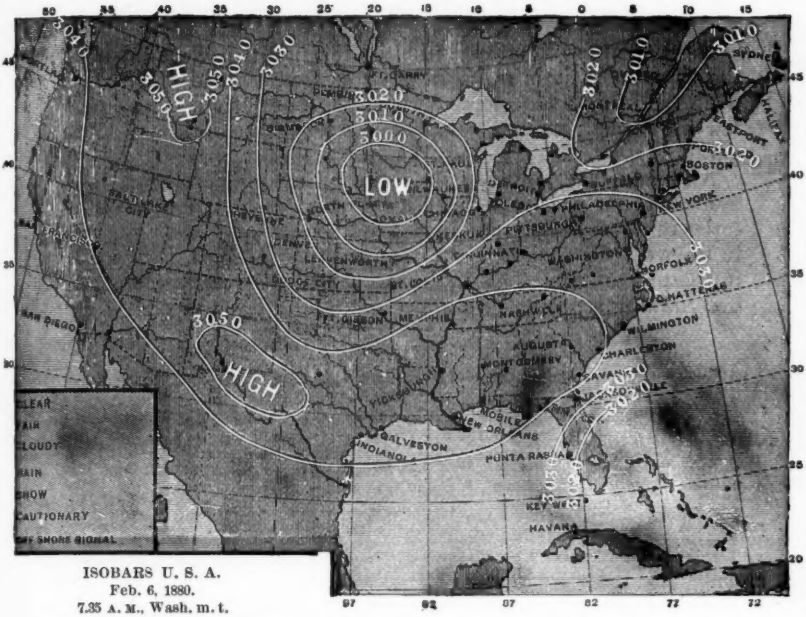
ISOBARS U. S. A.
Feb. 3, 1880.
7.35 A. M., Wash. m. t.



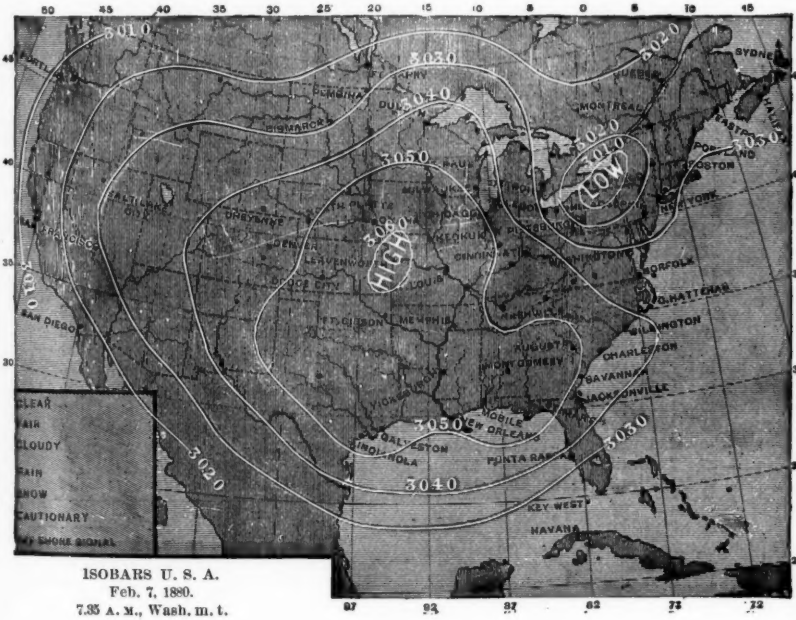
ISOBARS U. S. A.
Feb. 4, 1880.
7.35 A. M., Wash. m. t.



ISOBARS U. S. A.
Feb. 5, 1880.
7.35 A. M., Wash. m. t.



ISOBARS U. S. A.
Feb. 6, 1880.
7.35 A. M., Wash. m. t.



ISOBARS U. S. A.
Feb. 7, 1880.
7.35 A. M., Wash. m. t.

Only an approximate solution of the problem is claimed; at the same time it is quite satisfactory and if used will open a wide field for meteorological research, especially if there be a few additional stations established along the 50th and 55th parallels.

An exact determination of elevation of meteorological stations in the west would be of very great importance. Also a series of observations, conducted at elevated and lower stations in the west, for a whole year, as suggested by Lieut. Dunwoody in the preparation of his tables, would be of great assistance in determining a proper formula of reduction to sea-level.

TABLE VI.

For reducing pressures, at elevations not exceeding 1000 feet, to sea-level.

Formula: $\log \beta = \log \beta' + \dfrac{h}{60158{\cdot}6 \times \left(1 + \dfrac{2t - 64}{900}\right) \times \left(1 + \dfrac{h + 52252}{20886860}\right)}$; in this β' and t refer to the pressure and temperature at the upper station, h = altitude of station. Argument, h, β and t, $\beta = \beta'$ + correction from table.

T.	100′. Press'e 29″·4. C.	Diff. 100′.	Press'e 29″·9. C.	Diff. 100′.	Press'e 30″·4. C.	Diff. 100′.	T.	200′. Press'e 29″·3. C.	Diff. 100′.	Press'e 29″·8. C.	Diff. 100′.	Press'e 30″·3. C.	Diff. 100′.
80°	·102	·102	·103	·104	·105	·105	80°	·203	·102	·206	·104	·210	·105
75	·103	·103	·104	·105	·106	·106	75	·205	·103	·208	·105	·212	·106
70	·104	·104	·105	·106	·107	·108	70	·207	·104	·211	·106	·214	·108
65	·105	·105	·107	·107	·108	·109	65	·209	·105	·213	·107	·216	·109
60	·106	·106	·108	·108	·109	·110	60	·211	·106	·215	·108	·219	·110
55	·107	·107	·109	·109	·111	·111	55	·214	·107	·217	·109	·221	·111
50	·108	·108	·110	·110	·112	·112	50	·216	·108	·220	·110	·223	·112
45	·109	·109	·111	·111	·113	·113	45	·218	·109	·222	·111	·226	·113
40	·110	·111	·112	·113	·114	·115	40	·221	·111	·224	·113	·228	·115
35	·112	·112	·114	·114	·116	·116	35	·223	·112	·227	·114	·231	·116
30	·113	·113	·115	·115	·117	·117	30	·226	·113	·229	·115	·233	·117
25	·114	·114	·116	·116	·118	·118	25	·228	·114	·232	·116	·236	·118
20	·116	·116	·117	·118	·119	·120	20	·231	·116	·235	·118	·239	·121
15	·117	·117	·119	·119	·121	·121	15	·233	·117	·237	·119	·241	·122
10	·118	·119	·120	·121	·122	·123	10	·236	·119	·240	·121	·244	·123
5	·120	·120	·122	·122	·124	·124	5	·239	·120	·243	·122	·247	·124
0	·121	·122	·123	·124	·125	·126	0	·242	·122	·246	·124	·250	·126
−5	·123	·123	·125	·125	·127	·127	−5	·245	·123	·249	·125	·253	·127
−10	·124	·125	·126	·127	·128	·129	−10	·248	·125	·252	·127	·256	·129
−15	·126	·126	·128	·128	·130	·130	−15	·251	·126	·255	·128	·259	·130
−20	·127	·128	·129	·130	·131	·132	−20	·254	·128	·258	·130	·263	·132
−25	·129	·129	·131	·131	·133	·133	−25	·257	·129	·262	·131	·266	·134
−30	·130	·131	·133	·133	·135	·135	−30	·261	·131	·265	·133	·270	·136
−35	·132	·132	·134	·135	·137	·137	−35	·264	·133	·269	·135	·273	·137
−40	·134	·134	·136	·137	·138	·139	−40	·268	·135	·272	·137	·277	·138

300′.

T.	Press'e 29′′·2.		Press'e 29′′·7.		Press'e 30′′·2.	
	C.	Diff. 100′.	C.	Diff. 100′.	C.	Diff. 100′.
80°	·304	·102	·309	·104	·314	·105
75	·307	·103	·312	·105	·317	·106
70	·310	·104	·315	·106	·321	·108
65	·313	·105	·319	·107	·324	·109
60	·317	·106	·322	·108	·327	·110
55	·320	·107	·325	·109	·331	·111
50	·323	·109	·329	·110	·334	·112
45	·327	·110	·332	·111	·338	·113
40	·330	·111	·336	·113	·342	·115
35	·334	·112	·340	·114	·346	·116
30	·338	·113	·344	·115	·349	·117
25	·342	·114	·348	·116	·353	·118
20	·346	·116	·352	·118	·357	·120
15	·350	·117	·356	·119	·362	·121
10	·354	·119	·360	·121	·366	·123
5	·358	·120	·364	·122	·370	·124
0	·362	·122	·368	·124	·375	·126
− 5	·367	·123	·373	·125	·379	·127
−10	·371	·125	·377	·127	·384	·129
−15	·376	·126	·382	·128	·389	·130
−20	·381	·128	·387	·130	·394	·132
−25	·385	·129	·392	·132	·399	·134
−30	·390	·131	·397	·134	·404	·136
−35	·396	·133	·402	·135	·409	·137
−40	·401	·135	·408	·137	·415	·139

400′.

T.	Press'e 29′′·0.		Press'e 29′′·5.		Press'e 30′′·0.	
	C.	Diff. 100′.	C.	Diff. 100′.	C.	Diff. 100′.
80°	·403	·102	·410	·103	·417	·105
75	·407	·103	·414	·105	·421	·107
70	·411	·104	·418	·106	·425	·108
65	·416	·105	·423	·107	·430	·109
60	·420	·106	·427	·108	·434	·110
55	·424	·107	·432	·109	·439	·111
50	·429	·108	·436	·110	·444	·112
45	·434	·109	·441	·111	·449	·113
40	·438	·111	·446	·113	·454	·115
35	·443	·112	·451	·114	·459	·116
30	·448	·113	·456	·115	·464	·117
25	·453	·114	·461	·116	·469	·118
20	·459	·116	·467	·118	·475	·120
15	·464	·117	·472	·119	·480	·121
10	·470	·119	·478	·121	·486	·123
5	·475	·120	·483	·122	·491	·124
0	·481	·121	·489	·124	·497	·126
− 5	·487	·122	·495	·125	·503	·127
−10	·493	·124	·501	·127	·510	·129
−15	·499	·126	·507	·128	·516	·130
−20	·505	·128	·514	·130	·523	·132
−25	·512	·129	·520	·131	·529	·133
−30	·518	·131	·527	·133	·536	·135
−35	·525	·133	·534	·135	·543	·137
−40	·532	·135	·541	·137	·550	·139

500′.

T.	Press'e 28′′·9.		Press'e 29′′·4.		Press'e 29′′·9.	
	C.	Diff. 100′.	C.	Diff. 100′.	C.	Diff. 100′.
80°	·503	·102	·511	·103	·520	·105
75	·508	·103	·517	·104	·526	·106
70	·513	·104	·522	·106	·531	·107
65	·519	·105	·528	·107	·537	·108
60	·524	·106	·533	·108	·542	·110
55	·530	·107	·539	·109	·548	·111
50	·535	·108	·545	·110	·554	·112
45	·541	·109	·551	·111	·560	·113
40	·547	·111	·557	·112	·566	·114
35	·553	·112	·563	·113	·572	·115
30	·559	·113	·569	·115	·579	·117
25	·566	·114	·576	·116	·585	·118
20	·572	·116	·582	·118	·592	·120
15	·579	·117	·589	·119	·599	·121
10	·586	·119	·596	·121	·606	·123
5	·593	·120	·603	·122	·613	·124
0	·600	·122	·610	·124	·621	·126
− 5	·607	·123	·618	·125	·628	·127
−10	·615	·125	·625	·127	·636	·129
−15	·623	·126	·633	·128	·644	·130
−20	·631	·128	·641	·130	·652	·132
−25	·639	·129	·650	·131	·661	·134
−30	·647	·131	·658	·133	·669	·136
−35	·656	·133	·667	·135	·678	·137
−40	·664	·135	·676	·137	·687	·139

600′.

T.	Press'e 28′′·8.		Press'e 29′′·3.		Press'e 29′′·8.	
	C.	Diff. 100′.	C.	Diff. 100′.	C.	Diff. 100′.
80°	·602	·102	·613	·103	·623	·105
75	·609	·103	·619	·104	·630	·106
70	·615	·104	·625	·106	·636	·107
65	·621	·105	·632	·107	·643	·108
60	·628	·106	·639	·108	·650	·110
55	·634	·107	·646	·109	·657	·111
50	·641	·108	·653	·110	·664	·112
45	·648	·109	·660	·111	·671	·113
40	·656	·111	·667	·113	·678	·114
35	·663	·112	·674	·114	·686	·115
30	·670	·113	·682	·115	·694	·117
25	·678	·114	·690	·116	·702	·118
20	·686	·116	·698	·118	·710	·120
15	·694	·117	·706	·119	·718	·121
10	·702	·119	·714	·121	·726	·123
5	·710	·120	·723	·122	·735	·124
0	·719	·122	·732	·124	·744	·126
− 5	·728	·123	·741	·125	·753	·127
−10	·737	·125	·750	·127	·763	·129
−15	·746	·126	·759	·128	·772	·130
−20	·756	·128	·769	·130	·782	·132
−25	·765	·129	·779	·132	·792	·134
−30	·775	·131	·789	·133	·802	·136
−35	·786	·133	·799	·135	·813	·137
−40	·796	·135	·810	·137	·824	·139

700′.

T.	Press'e 28″·7.		Press'e 29″·2.		Press'e 29″·7.	
	C.	Diff. 100′.	C.	Diff. 100′.	C.	Diff. 100′.
80°	·702	·102	·714	·103	·726	·105
75	·709	·103	·721	·104	·733	·106
70	·716	·104	·729	·106	·741	·107
65	·724	·105	·736	·107	·749	·108
60	·731	·106	·744	·108	·757	·110
55	·739	·107	·752	·109	·765	·111
50	·747	·108	·760	·110	·773	·112
45	·755	·110	·768	·111	·782	·113
40	·764	·111	·777	·113	·790	·115
35	·772	·112	·786	·114	·799	·116
30	·781	·113	·795	·115	·808	·117
25	·790	·115	·804	·117	·817	·119
20	·799	·116	·813	·118	·827	·120
15	·808	·117	·822	·119	·836	·121
10	·818	·119	·832	·121	·846	·123
5	·828	·120	·842	·122	·857	·124
0	·838	·122	·852	·124	·867	·126
− 5	·848	·123	·863	·125	·878	·127
−10	·859	·125	·874	·127	·889	·129
−15	·870	·126	·885	·128	·900	·130
−20	·881	·128	·896	·130	·911	·132
−25	·892	·130	·907	·132	·923	·134
−30	·904	·131	·919	·134	·935	·136
−35	·915	·133	·931	·135	·947	·138
−40	·928	·135	·944	·137	·960	·140

800′.

T.	Press'e 28″·6.		Press'e 29″·1.		Press'e 29″·6.	
	C.	Diff. 100′.	C.	Diff. 100′.	C.	Diff. 100′.
80°	·800	·102	·814	·103	·828	·105
75	·809	·103	·823	·104	·837	·106
70	·817	·104	·831	·105	·845	·107
65	·826	·105	·840	·107	·854	·108
60	·834	·106	·849	·108	·863	·110
55	·843	·107	·858	·109	·873	·111
50	·852	·108	867	·110	·882	·112
45	·862	·109	·877	·111	·892	·113
40	·871	·111	·887	·113	·902	·115
35	·881	·112	·896	·114	·912	·116
30	·891	·113	·907	·115	·922	·117
25	·901	·115	·917	·117	·933	·119
20	·912	·116	·928	·118	·944	·120
15	·922	·117	·939	·119	·955	·121
10	·934	·119	·950	·121	·966	·123
5	·945	·120	·961	·122	·978	·124
0	·956	·122	·973	·124	·990	·126
− 5	·968	·123	·985	·125	1·002	·127
−10	·980	·125	·997	·127	1·014	·129
−15	·992	·126	1·010	·129	1·027	·131
−20	1·005	·128	1·023	·130	1·040	·132
−25	1·018	·130	1·036	·132	1·053	·134
−30	1·031	·131	1·049	·134	1·067	·136
−35	1·045	·133	1·063	·136	1·081	·138
−40	1·059	·135	1·078	·138	1·096	·140

900′.

T.	Press'e 28″·5.		Press'e 29″·0.		Press'e 29″·5.	
	C.	Diff. 100′.	C.	Diff. 100′.	C.	Diff. 100′.
80°	·899	·102	·915	·103	·930	·105
75	·908	·103	·924	·104	·940	·106
70	·917	·104	·934	·105	·950	·107
65	·927	·105	·943	·107	·960	·108
60	·937	·106	·953	·108	·970	·110
55	·947	·107	·964	·109	·980	·111
50	·957	·108	·974	·110	·991	·112
45	·968	·110	·985	·111	1·002	·113
40	·979	·111	·996	·113	1·013	·115
35	·990	·112	1·007	·114	1·024	·116
30	1·001	·113	1·018	·115	1·036	·117
25	1·012	·115	1·030	·117	1·048	·119
20	1·024	·116	1·042	·118	1·060	·120
15	1·036	·117	1·054	·119	1·072	·121
10	1·048	·119	1·067	·121	1·085	·123
5	1·061	·120	1·080	·122	1·098	·124
0	1·074	·122	1·093	·124	1·112	·126
− 5	1·087	·123	1·106	·125	1·125	·127
−10	1·101	·125	1·120	·127	1·140	·129
−15	1·115	·126	1·134	·129	1·154	·131
−20	1·129	·128	1·149	·130	1·169	·132
−25	1·144	·130	1·164	·132	1·184	·134
−30	1·159	·131	1·179	·134	1·199	·136
−35	1·174	·133	1·195	·136	1·215	·138
−40	1·190	·135	1·211	·138	1·232	·140

1000′.

T.	Press'e 28″·4.		Press'e 28″·9.		Press'e 29″·4.	
	C.	Diff. 100′.	C.	Diff. 100′.	C.	Diff. 100′.
80°	·997	·102	1·014	·103	1·032	·105
75	1·007	·103	1·025	·104	1·043	·106
70	1·018	·104	1·036	·105	1·053	·107
65	1·028	·105	1·046	·107	1·065	·109
60	1·039	·106	1·058	·108	1·076	·110
55	1·050	·107	1·069	·109	1·087	·111
50	1·062	·108	1·081	·110	1·099	·112
45	1·074	·110	1·093	·111	1·111	·113
40	1·086	·111	1·105	·113	1·124	·115
35	1·098	·112	1·117	·114	1·136	·116
30	1·110	·113	1·130	·115	1·149	·117
25	1·123	·115	1·143	·117	1·163	·119
20	1·136	·116	1·156	·118	1·176	·120
15	1·149	·117	1·170	·120	1·190	·122
10	1·163	·119	1·184	·121	1·204	·123
5	1·177	·120	1 198	·122	1·219	·125
0	1·192	·122	1·213	·124	1·233	·126
− 5	1·206	·123	1·228	·125	1·249	·128
−10	1·221	·125	1·243	·127	1·264	·129
−15	1·237	·126	1·259	·129	1·280	·131
−20	1·253	·128	1·275	·131	1·297	·133
−25	1·269	·130	1·291	·132	1·314	·135
−30	1·286	·132	1·308	·134	1·331	·136
−35	1·303	·133	1·326	·136	1·349	·138
−40	1·321	·135	1·344	·138	1·367	·140

ART. XLVII.—*Neumann's Method of calibrating Thermometers, with ways of getting columns for calibration;* by T. RUSSELL, U. S. Lake Survey.

NEUMANN'S method of calibrating thermometers has very considerable advantages over those of Bessel and of Hällström, which are the ones in common use. In the computations of the corrections by this method the numbers used are always small, and there is entire freedom from arbitrary assumptions. Without at all increasing the work of reduction, the calibrating columns can be used to the greatest advantage, and even when all the regular observations required by the method are not obtained, the corrections can nevertheless be derived in a definite manner. The method combines, in short, the greatest simplicity, elegance and exactness.

An essential feature of the method is that the columns used must be as nearly as possible equal in length to a whole number of intervals between the points for which the corrections are required; if, for instance, for every ten degrees, the lengths of the columns used must then be about ten, twenty, thirty, etc. degrees. Although it is not necessary to have all the possible columns of this kind, yet the greater the number obtained the simpler becomes the reduction. Calling the points for which the corrections are required principal points, the columns obtained are to be measured with the lower ends near all of the principal points, as far as the lengths of the columns will permit. The lengths of the columns being as stated above, the upper ends will also be in the vicinity of principal points.

For a knowledge of this method the writer is indebted to an article by M. Thiesen, in the November number for 1879, of the Zeitschrift der österreichischen Gesellschaft für Meteorologie. The notation given there is followed here. Denote the calibration corrections at the principal points of a thermometer by $\Delta_0\ \Delta_1\ \Delta_2 \ldots . \Delta_n$, and the corrections to the intervals between successive principal points by $\delta_0\ \delta_1\ \delta_2$, etc., then we have in general:

$$\delta_i = \Delta_{i+1} - \Delta_i$$

Let the general designation of principal points near the upper ends of columns be k, and that of points near the lower ends be i. Denote the volume of any column by $f_{(k-i)}$ and its apparent length, that is the difference of the readings of the upper end and lower end in a given position, by (k, i). If the corrections of the small spaces which lie between the ends of the

column and the principal points i, and k, be neglected, the following relation holds:

$$f_{(k-i)} = (k, i) + \Delta_k - \Delta_i$$

If the column is moved and placed with the ends near other principal points, other similar equations will be obtained, in which the left side will be the same, but on the right side in place of i and k, there will be in succession $i+1$ and $k+1$, $i+2$ and $k+2$, etc. If each of these equations is subtracted from the equation following it, a new set of equations will result of the form:

$$\delta_i - \delta_k = (k+1, i+1) - (k, i)$$

The further development of the method can best be shown in the course of the example of calibration which follows:

Thermometer, Green, 4470, is divided to fifths of a degree, Fahrenheit. The apparent lengths of columns given below are from estimated readings of the ends to the nearest tenth of a division, or 0°·02. As it is not intended to use this thermometer at temperatures above 122°, no special effort was made to get the corrections above that point. On account of this the calibration falls into two parts, which illustrate both branches of the method; the one where all requisite columns are used, and the other where some of the columns are wanting. Part first consists in the derivation of the corrections at 77°, 122° and 167°, with columns of 45°, 90° and 135°. Part second consists in the derivation of the corrections for every tenth degree up to 122°, by the use of columns which are in length multiples of ten degrees.

Table I contains the measured lengths of columns for the first part of the work.

TABLE I.

Apparent lengths of columns.

45° column.		90° column.		135° column.	
32·77	44·68	32·122	90·07	32·167	134·61
	+0·03		+0·02		+0·07
77·122	44·71	77·167	90·09	77·212	134·68
	+0·01		+0·02		
122·167	44·72	122·212	90·11		
	+0·03				
167·212	44·75				

Table II is formed by placing vertically the first horizontal line of differences of table I, and parallel to it the other lines of differences, beginning one line lower each time. This being done the numbers in the vertical lines are copied horizontally, with the signs changed. These two parts of the table are separated by a diagonal line of double zeros.

TABLE II.

Values of $\delta_i - \delta_k$ in 0°·01 F.

	32	77	122	167
32	00	−03	−02	−07
77	+03	00	−01	−02
122	+02	+01	00	−03
167	+07	+02	+03	00
Sums	+12	00	00	−12

The first column is composed of the following values, in which δ_{32}, is the correction of the interval 32° to 77°, δ_{77}, that of 77° to 122° and so on:

$$\begin{aligned} \delta_{32} - \delta_{32} &= 00 \\ \delta_{32} - \delta_{77} &= +03 \\ \delta_{32} - \delta_{122} &= +02 \\ \delta_{32} - \delta_{167} &= +07 \end{aligned}$$

by summing, there results: $4\delta_{32} - (\Delta_{212} - \Delta_{32}) = +12$.

The second column of table II is made up as follows:

$$\begin{aligned} -\delta_{32} + \delta_{77} &= -03 \\ \delta_{77} - \delta_{77} &= 00 \\ \delta_{77} - \delta_{122} &= +01 \\ \delta_{77} - \delta_{167} &= +02 \end{aligned}$$

and by summing, as before; $4\delta_{77} - (\Delta_{212} - \Delta_{32}) = 00$. In like manner the other columns give similar equations, and since Δ_{212} and Δ_{32} are zero, we have:

$$\begin{aligned} 4\,\delta_{32} &= +12 \quad \therefore \quad \delta_{32} = +0°{\cdot}03 \\ 4\,\delta_{77} &= 00 \quad \therefore \quad \delta_{77} = 00 \\ 4\,\delta_{122} &= 00 \quad \therefore \quad \delta_{122} = 00 \\ 4\,\delta_{167} &= -12 \quad \therefore \quad \delta_{167} = -0°{\cdot}03 \end{aligned}$$

by adding these values of δ, the corrections at 77°, 122° and 167° are found to be alike, and equal to +0°·03.

In the second part of the work no measurements were made with a ten-degree column, and therefore the symmetry of the first part will be wanting. The lengths of the columns as measured are given in table III. Before each line of lengths is given the approximate scale-reading of the lower ends of the columns.

TABLE III.

Lower end.	Apparent lengths of columns.						
32.	20·36	29·80	39·77	49·55	59·94	69·65	80·55
42.	20·38	29·82	39·78	49·57	59·90	69·65	80·47
52.	20·45	29·91	39·87	49·61	60·02	69·75	
62.	20·47	29·88	39·81	49·62	59·98		
72.	20·46	29·88	39·84	49·60			
82.	20·42	29·90	39·81				
92.	20·49	29·86					
102.	20·44						

Table IV is formed in the same way as table II. It will be noticed that there are two series of blanks corresponding to the 10° column of which the observations are wanting.

TABLE IV.

Values of $\delta_i - \delta_k$ and residuals in 0°·01 F.

	32	42	52	62	72	82	92	102	112
32	00		−02	−02	−01	−02	+04	00	+08
42		00		−07	−09	−09	−04	−12	−10
52	+02 − 1		00		−02	+03	+06	−01	+04
62	+02 − 3	+07 + 1		00		+01	00	−03	+02
72	+01 0	+09 + 1	+02 − 2		00		+04	−02	+03
82	+02 − 3	+09 − 1	−03 + 1	−01 + 1		00		−07	+04
92	−04 + 1	+04 + 2	−06 + 2	00 − 2	−04 0		00		+05
102	00 + 2	+12 0	+01 0	+03 + 1	+02 0	+07 − 3		00	
112	−08 + 3	+10 − 5	−04 − 2	−02 − 2	−03 − 2	−04 + 1	−05 + 3		00
Sums	−05	+51	−12	−09	−17	−04	+05	−25	+16

The sum of the numbers in the last horizontal line must be zero. This gives a check on the summing of the columns and the copying with signs changed. Another check on the work is this: that the differences of any two quantities in the same horizontal line should be the same, within the limits of the errors of observation.

Analyzing by a process similar to that used for table II, the following equations will be found, in which δ_{32} is the correction of the interval 32° to 42°; δ_{42}, that of 42° to 52° and so on.

		Approximations.		
		First.	Second.	Third.
$8\,\delta_{32} = \Delta_{122} - \Delta_{32} - \delta_{42} \quad -05$	$\delta_{32} =$	−·003	−·013	−·013
$7\,\delta_{42} = \Delta_{122} - \Delta_{32} - \delta_{32} - \delta_{52} + 51$	$\delta_{42} =$	+·077	+·080	+·082
$7\,\delta_{52} = \Delta_{122} - \Delta_{32} - \delta_{42} - \delta_{62} - 12$	$\delta_{52} =$	−·013	−·023	−·024
$7\,\delta_{62} = \Delta_{122} - \Delta_{32} - \delta_{52} - \delta_{72} - 09$	$\delta_{62} =$	−·009	−·004	−·003
$7\,\delta_{72} = \Delta_{122} - \Delta_{32} - \delta_{62} - \delta_{82} - 17$	$\delta_{72} =$	−·020	−·019	−·019
$7\,\delta_{82} = \Delta_{122} - \Delta_{32} - \delta_{72} - \delta_{92} - 04$	$\delta_{82} =$	−·001	·000	−·001
$7\,\delta_{92} = \Delta_{122} - \Delta_{32} - \delta_{82} - \delta_{102} + 05$	$\delta_{92} =$	+·011	+·016	+·017
$7\,\delta_{102} = \Delta_{122} - \Delta_{32} - \delta_{92} - \delta_{112} - 25$	$\delta_{102} =$	−·031	−·037	−·038
$8\,\delta_{112} = \Delta_{122} - \Delta_{32} - \delta_{102} \quad +16$	$\delta_{112} =$	+·024	+·031	+·032

The values of δ, are derived from these equations by approximation. As seven times the correction of any interval may be reasonably assumed to be large as compared with the sum of the corrections of two adjoining intervals, approximate values can be derived from these equations by neglecting the δ on the right hand side. Δ_{122} is known from the first part of the work to be +0°·03, and Δ_{32} is zero. When the first approximation is made, the values found can be substituted on the right hand side of the equations and another set of values derived more accurate than the first. A few such processes will give the values of δ with sufficient accuracy. From these

final values of δ, the calibration corrections Δ_i given below are obtained by the formula $\Delta_{i+1}=\Delta_i+\delta_i$.

	Correction. Δ_i
32 =	0·00
42 =	−0·01
52 =	+0·07
62 =	+0·04
72 =	+0·04
82 =	+0·02
92 =	+0·02
102 =	+0·04
112 =	0·00
122 =	+0·03

To get some idea of the accuracy of the determination, the differences of observed and computed values of $\delta_i-\delta_k$ are given in table IV, in small figures, under each of the values. These residuals correspond to a probable error in any observed $\delta_i-\delta_k$ of about $\pm 0°·013$: and the probable error of any calibration correction will not exceed $\pm 0°·01$.

The calibration of a thermometer by this method where any of the observations with a particular column are lacking offers no special difficulty. When the observations are far from being as nearly complete as in the example just presented, good results can nevertheless be obtained, but the computation then becomes more tedious. In calibrating, every series of measurements with a column ought to be repeated in the reverse of the order first made. This will be a guard against large errors; and moreover the means of the two measurements will be free of errors arising from change of temperature of the column, provided its temperature is rising or falling uniformly.

Thermometers with reservoirs at the top of the tube are the easiest and safest to calibrate. This reservoir should be pear-shaped and of a capacity sufficient to hold at least as much mercury as the tube from freezing to boiling points. To obtain columns for calibrating, hold the thermometer vertical, with the bulb up, and give it a slight shock by the sudden stopping of a downward motion. This will be apt to detach a column of indefinite length or cause the mercury to run from the bulb. In case this does not occur in a few trials heat the thermometer so as to bring more mercury into the tube, and try it again. It will finally succeed with some greater length of column. In case the mercury runs from the bulb let it go until it enters the reservoir and partially occupies it. Then invert the thermometer quickly and the connection between the mercury in the bulb and that above will be broken. In case the portion detached is not the length of a column required move the mercury until it partially occupies the reser-

voir again. Then take the thermometer in the right hand, tap the index finger of the left hand with the reservoir-end, holding the instrument about horizontal. This will detach a greater or less portion of the mercury, depending on the intensity of the shock. If what is left is not of the required length bring back the mercury to the entrance of the reservoir; a few taps on the finger, as before, will cause the mercury to reunite. This process can be done over and over until a column of the required length is obtained.

In this way within half an hour a person can usually obtain a working column to a few tenths of a degree without any risk to the thermometer. Care should be taken in deriving the columns not to let all the detached mercury run into the reservoir, but to have a portion always projecting into the tube. If it does get into the reservoir, or there is not enough in the tube to cause it to run down by a sharp, quick motion when the thermometer is held vertical, the reservoir must be heated. An alcohol lamp is preferable for this purpose. The expansion of what little air there is in the reservoir will almost always drive down the mercury, but sometimes it requires the volatilization of the mercury itself. This difficulty of getting the mercury to run down the tube is in the way of obtaining short columns, especially in very capillary tubes.

Short columns can best be obtained from the bulb, in case the thermometer has but little tubing below freezing point so as to allow the mercury to sink into the bulb when put in a cooling mixture, as of salt and pounded ice. To obtain columns in this way, bring down the detached portion of mercury from the reservoir and let it join the main body of mercury in the bulb. It will be found that this junction will not be perfect, a slight bubble always remaining at the place of joining. Place the bulb in a cooling mixture until the top of the column is about as far above the bulb as the length of column desired; in the meantime the bubble, of which mention has been made, will have entered the bulb. Now take the thermometer in the right hand and hold it inclined, with the bulb down. A few light shocks by the sudden stopping of a rapid motion in the direction of the thermometer stem will bring the bubble to the entrance of the tube. The expansion of the mercury as the temperature rises will drive the short column before it. By this process also the mercury may be perfectly reunited after the calibration is completed, by cooling until all the mercury runs into the bulb, when a little jarring of the thermometer, as before, will cause the bubble to disappear.

Another method of getting columns of definite length is described in *Fischer's Geodäsie*, credited to Hansteen. The pinciple consists in getting a small bubble of air in the column

of mercury, but not large enough to occupy the whole cross-section of the tube; then by very slow heating or cooling when the desired length of column is above the bubble it may be detached by a sudden jar. To operate successfully, according to this method, a thermometer of large bore is required. In the case of a thermometer without a reservoir at the top these latter methods are the only ones that can be safely used. Egen's method of directing the flame of a blowpipe on the tube should never be followed.

In selecting a thermometer some idea of the nature of the bore, whether regular or not, can be formed by inspection without the aid of detached columns. If examination with a reveals a straight smooth exterior it generally denotes the same interior qualities.

Art. XLVIII.—*Notice of William Hallowes Miller;* by J. P. Cooke.*

William Hallowes Miller, who was elected Foreign Honorary Member of this Academy in the place of C. F. Naumann, May 26th, 1874, died at his residence in Cambridge, England, on the 20th of May, 1880, at the age of 79, having been born at Velindre in Wales, April 6th, 1801. His life was singularly uneventful even for a scholar. Graduating with mathematical honors at Cambridge in 1826 he became a fellow of his College (St. Johns) in 1829, and was elected Professor of Mineralogy in the University in 1832. Amidst the calm and elegant associations of this ancient English University, Miller passed a long and tranquil life,—crowded with useful labors, honored by the respect and love of his associates and blessed by congenial family ties. This quiet student life was exactly suited to his nature, which shunned the bustle and unrest of our modern world. For relaxation even he loved to seek the retired valleys of the Eastern Alps; and the description which he once gave to the writer, of himself sitting at the side of his wife amidst the grand scenery, intent on developing crystallographic formulæ while the accomplished artist traced the magnificent outlines of the Dolomite Mountains, was a beautiful idyl of science.

Miller's activities, however, were not confined to the University. In 1838 he became a Fellow of the Royal Society, and in 1856 he was appointed its Foreign Secretary,—a post for which he was eminently fitted and which he filled for many years. In 1843 he was selected one of a committee to superin-

* Read before the American Academy of Arts and Sciences, Boston, and to appear in the Proceedings.

tend the construction of the new Parliamentary standards of length and weight to replace those which had been lost in the fire which consumed the Houses of Parliament in 1834, and to Professor Miller was confided the construction of the new standard of weight. His work on this important committee, described in an extended paper published in the Philosophical Transactions for 1856, was a model of conscientious investigation and scientific accuracy. Professor Miller was subsequently a member of a new Royal Commission for "examining into and reporting on the state of the secondary standards, and for considering every question which could affect the primary, secondary and local standards"; and in 1870 he was appointed a member of the "Commission Internationale du Mètre." His services on this commission were of great value and it has been said that "there was no member whose opinions had greater weight in influencing a decision upon any intricate and delicate questions."

Valuable, however, as were Professor Miller's public services on these various commissions his chief work was at the University. His teacher, Dr. William Whewell, afterwards the Master of Trinity College, was his immediate predecessor in the Professorship of Mineralogy at Cambridge. This great scholar, whose encyclopædic mind could not long be confined in so narrow a field, held the Professorship only four years, but during this period he devoted himself with his usual enthusiasm to the study of crystallography, and he accomplished a most important work in attracting to the same study young Miller, who brought his mathematical training to its elucidation. It was the privilege of Professor Miller to accomplish a unique work, for the like of which a more advanced science, with its multiplicity of details, will offer few opportunities.

The foundations of crystallography had been laid long before Miller's time. Haüy is usually regarded as the founder of the science; for he first discovered the importance of cleavage, and classed the known facts under a definite system. Taking cleavage as his guide and assuming that the forms of cleavage were not only the *primitive forms* of crystals as a whole, but also the forms of their *integrant molecules*, he endeavored to show that all secondary forms might be derived from a few primary forms, regarded as elements of nature, by means of *decrements* of molecules at their edges. In like manner he showed that all the forms of a given mineral, like fluor spar or calcite, might be built up from the integrant molecules by skilfully placing together the primitive forms. Haüy's dissection of crystals in a manner which appeared to lead to their ultimate crystalline elements gained for his system great popular attention and applause. The system was developed with great perspicuity

and completeness in a work remarkable for the vivacity of its style and the felicity of its illustration. Moreover, a simple mathematical expression was given to the system, and the notation which Haüy invented to express the relation of the secondary to the primary forms, as modified and improved by Lèvy, is still used by the French mineralogists.

The system of Haüy, however, was highly artificial and only prepared the way for a simpler and more general expression of the facts. The German crystallographer Weiss seems to have been the first to have recognized the truth that the decrements of Haüy were merely a mechanical mode of representing the fact that all the secondary faces of a crystal make intercepts on the edges of the primitive form which are simple multiples of each other; and this general conception once gained it was soon seen that these ratios could be as simply measured on the axes of symmetry of the crystal as on the edges of the fundamental forms; and, moreover, that when crystal forms are viewed in their relation to these axes a more general law becomes evident, and the artificial distinction between primary and secondary forms disappears.

Thus became slowly evolved the conception of a crystal as a group of similar planes symmetrically disposed around certain definite and obvious systems of axes, and so placed that the intercepts, or parameters, on these axes bore to each other a simple numerical ratio. Representing by $a : b : c$ the ratio of the intercepts of a plane on the three axes of a crystal of a given substance, then the intercepts of every other plane of this, or of any other crystal of the same substance, conform to the general proportion $m\,a : n\,b : p\,c$, in which m, n, p are three simple whole numbers. This simple notation devised by Weiss expressed the fundamental law of crystallography, and the conception of a crystal as a system of planes symmetrically distributed according to this law was a great advance beyond the decrements of Haüy, an advance not unlike that of astronomy from the system of vortices to the law of gravitation. Yet, as the mechanism of vortices was a natural prelude to the law of Newton, so the decrements of Haüy prepared the way for the wider views of the German crystallographers.

Whether Weiss or Mohs contributed most to advance crystallography to its more philosophical stage, it is not important here to inquire. Each of these eminent scholars did an important work in developing and diffusing the larger ideas, and in showing by their investigations that the facts of nature corresponded to the new conceptions. But to Carl Friedrich Naumann, Professor at the time in the "Bergakademie zu Freiberg," belongs the merit of first developing a complete system of theoretical crystallography based on the laws of sym-

metry and axial ratios. His "Lehrbuch der reinen und angewandten Krystallographie," published in two volumes at Leipzig in 1830, was a remarkable production, and seemed to grasp the whole theory of the external forms of crystals. Naumann used the obvious and direct methods of analytical geometry to express the quantitative relations between the parts of a crystal; and although his methods are often unnecessarily prolix and his notation awkward, his formulæ are well adapted to calculation, and easily intelligible to persons moderately disciplined in mathematics.

But, however comprehensive and perfect in its details, the system of Naumann was cumbrous, and lacked elegance of mathematical form. This arose chiefly from the fact that the old methods of analytical geometry were unsuited to the problems of crystallography; but it resulted also from a habit of the German mind to dwell on details and give importance to systems of classification. To Naumann the six crystalline systems were as much realities of nature as were the forms of the integrant molecules to Haüy, and he failed to grasp the larger thought which includes all partial systems in one comprehensive plan.

Our late colleague, Professor Miller, on the other hand, had that power of mathematical generalization which enabled him to properly subordinate the parts to the whole, and to develop a system of mathematical crystallography of such simplicity and beauty of form that it leaves little to be desired. This was the great work of his life and a work worthy of the University which had produced the "Principia." It was published in 1839 under the title "A Treatise on Crystallography," and in 1863 the substance of the work was reproduced in a more perfect form, still more condensed and generalized, in a thin volume of only eighty-six pages, which the author modestly called "A Tract on Crystallography."

Miller began his study of crystallography with the same materials as Naumann; but in addition he adopted the beautiful method of Franz Ernst Neumann of referring the faces of a crystal to the surface of a circumscribed sphere by means of radii drawn perpendicular to the faces. The points where the radii meet the spherical surface are the poles of the faces, and the arcs of great circles connecting these poles may obviously be used as a measure of the angles between the crystal faces. This invention of Neumann's was the germ of Miller's system of crystallography; for it enabled the English mathematician to apply the elegant and compendious methods of spherical trigonometry to the solution of crystallographic problems; and Professor Miller always expressed his great indebtedness to Neumann not only for this simple mode of

defining the position of the faces of a crystal, but also for his method of representing the relative position of the poles of the faces on a plane surface by a beautiful application of the methods of stereographic and gnomonic projection. This method of representing a crystal shows very clearly the relations of the parts, and was undoubtedly of great aid to Miller in assisting him to generalize his deductions.

From the outset Professor Miller apprehended more clearly than any previous writer the all-embracing scope of the great law of crystallography. He opens his Treatise with its enunciation, and from this law as the fundamental principle of the subject the whole of his system of crystallography is logically developed. Beyond this all that is peculiar to Miller's system is involved in two or three general theorems. The rest of his "Treatise" consists of deductions from these theorems and their application to particular cases. These given and the rest could be at once developed by any scholar who was familiar with the facts of crystallography; and the circumstance that its essential features can be so briefly stated is sufficient to show how exceedingly simple the system is. At the same time, it is wonderfully comprehensive, and the student who has mastered it feels that it presents to him in one grand view the entire scheme of crystal forms, and that it greatly helps him to comprehend the scheme as a whole, and not simply as the sum of certain distinct parts. So felt Professor Miller himself; and, while he regarded the six systems of crystals of the German crystallographers as natural divisions of the field, he considered that these divisions were bounded by artificial lines which have no deeper significance than the boundary lines on a map. How great the unfolding of the science from Haüy to Miller, and yet now we can see the great fundamental ideas shining through the obscurity from the first. What we now call the parameters of a crystal were to Haüy the fundamental dimensions of his "integrant molecules," our indices were his "decrements," and our conceptions of symmetry his "fundamental forms." There has been nothing peculiar, however, in the growth of crystallography. This growth has followed the usual order of science, and here as elsewhere the early gross material conceptions have been the stepping stones by which men rose to higher things. In sciences like chemistry, which are obviously still in the earlier stages of their development, it would be well if students would bear in mind this truth of history, and not attach undue importance to structural formulæ and similar mechanical devices, which, although useful for aiding the memory, are simply hindrances to progress as soon as the necessity of such assistance is passed. And when the life of a great master of science has ended, it is well to look back

over the road he has traveled, and while we take courage in his success consider well the lesson which his experience has to teach; and, as progress in this world's knowledge has ever been from the gross to the spiritual, may we not rejoice as those who have a great hope.

Although the exceeding merit of the "Treatise on Crystallography" casts into the shade all that was subordinate, we must not omit to mention that Professor Miller published an early work on Hydrostatics and numerous shorter papers on Mineralogy and Physics, which were all valuable, and constantly contained important additions to knowledge. Moreover, the "New Edition of Phillips' Mineralogy" which he published in 1852 in connection with H. J. Brooke, owed its chief value to a mass of crystallographic observations which he had made with his usual accuracy and patience during many years and there tabulated in his concise manner. As has been said by one of his associates in the Royal Society, "it is a monument to Miller's name although he almost expunged that name from it.* It is due to Professor Miller's memory that his works should be collated, and especially that by a suitable commentary his "Tract on Crystallography" should be made accessible to the great body of the students of physical science, who have not as a rule the ability or training which enables them to apprehend a generalization when solely expressed in mathematical terms. The very merits of Professor Miller's book as a scientific work renders it very difficult to the average student, although it only involves the simplest form of algebra and trigonometry.

Independence, breadth, accuracy, simplicity, humility, courtesy are luminous words which express the character of Professor Miller. In his genial presence the young student felt encouraged to express his immature thoughts, which were sure to be treated with consideration, while from a wealth of knowledge the great master made the error evident by making the truth resplendent. It was the greatest satisfaction to the inexperienced investigator when his observations had been confirmed by Professor Miller, and he was never made to feel discouraged when his mistakes were corrected. The writer of this notice regards it as one of the great privileges of his youth, and one of the most important elements of his education, to have been the recipient of the courtesies and counsel of three great Englishmen of science, who have always been "his own ideal knights," and these noble knights were Faraday, Graham and Miller.

* Obituary Notices from the Proceedings of the Royal Society, No. 206, 1880, to which the writer has been indebted for several biographical details.

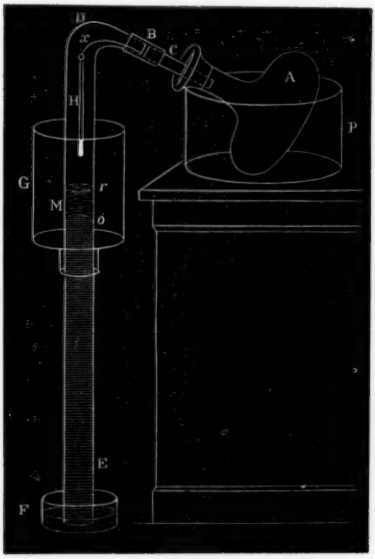
ART. XLIX.—*Preliminary Note on the Existence of Ice and other Bodies in the Solid State at Temperatures far above their ordinary Melting Points;* by THOMAS CARNELLEY, D.Sc., Professor of Chemistry in Firth College, Sheffield.*

IN the present communication I have the honor to lay before the Royal Society a detailed description of experiments, proving that under certain conditions it is possible for ice and other bodies to exist in the solid state at temperatures far above their ordinary melting points. On a future occasion I hope to submit to the Society a full account of the investigation of which these experiments form a part, together with the conclusions to be drawn therefrom. The bodies whose behavior I propose to discuss at present are ice and mercuric chloride.

Ice.

In the case of ice the great difficulty to be overcome is to maintain the pressure in the containing vessel below 4·6^{mm}, i. e.,

1.



the tension of aqueous vapor at the freezing point, for it will be easily understood that if the ice be but slightly heated the quantity of vapor given off would soon be sufficient to raise the pressure above that point. After several fruitless attempts the

* From the Proceedings of the Royal Society, January 6, 1881.

following plan, involving the principle of the cryophorus, was adopted.

A strong glass bottle, such as is used for freezing water by means of Carré's pump, was fitted with a cork and glass tube C (fig. 1), and the cork well fastened down by copper wire and paraffin wax. A and C were then filled with mercury, and C connected with the end of the tube DE by means of the piece of stout india-rubber pump tubing B, a thermometer having been previously attached by the wire x to the lip of the tube at B. The connection at B was made tight by fine copper wire. The tube DE was about one inch in diameter, and about four feet long from the bend to the end E; after connection with C it was completely filled with mercury, care being taken to expel the air from A, C and DE as completely as possible; the whole was then inverted over the mercurial trough F, as shown in the figure, when the mercury fell to o, the ordinary height of the barometer. The mercury was run out of A by tilting up the bottle and inclining the tube DE. By this means a Torricellian vacuum was obtained from A to o. DE was next brought to the vertical, and the bottle A placed in the trough P. A tin bottle G without a bottom was fitted with a cork, so that it might slide somewhat stiffly along DE.

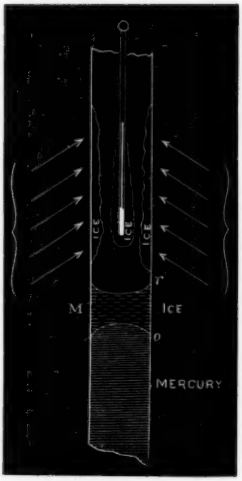
To begin with, the tin bottle was placed in the position G and filled with a freezing mixture of salt and ice. Some boiled water was then passed up the tube DE, sufficient to form a column at M about two inches deep. The thermometer H had been previously arranged, so that its bulb might be one or two inches above the surface of the water M. The bottle A was next surrounded by a good quantity of a freezing mixture of salt and ice, in order that any vapor given off from the water at M might be condensed in A as fast as it was formed, and the internal pressure might never be more than about 1·0 to 1·5^{mm}. When A had been sufficiently cooled, which required about fifteen minutes, the tin vessel G was slid down the tube DE, and its freezing mixture removed. The water at M had then solidified to a mass of ice, which on heating with the flame of a Bunsen's burner melted either wholly or partially, and the liquid formed began at once to boil. The fusion commenced first at the bottom of the column of ice, whereas the upper part fused only with difficulty, and required rather a strong heat. The fusion in this case was probably due to the steam evolved from the lower portions of the ice column being imprisoned and unable to escape, and hence producing pressure sufficient to cause fusion.

When the greater part of the ice had been melted the tube was tightly clasped by the hand, the heat of which was sufficient to produce a somewhat violent ebullition. The liquid in

boiling splashed up the side of the tube and on to the bulb of the thermometer, where it froze into a solid mass, as represented in fig. 2. By this means the ice was obtained in moderately thin layers. The tube at the points indicated by the arrows was then strongly heated by the flame of a Bunsen's burner, with the following results:—

The ice attached to the sides of the tube at first slightly fused, because the steam evolved from the surface of the ice next the glass being imprisoned between the latter and the overlying strata of ice, could not escape, and hence produced pressure sufficient to cause fusion, but as soon as a vent-hole had been made fusion ceased, and the whole remained in a solid state, and neither the ice on the sides of the tube nor that on the bulb of the thermometer could be melted, however great the heat applied, the ice merely volatilizing without previous melting. The thermometer rose to temperatures varying between 120° and 180° in different experiments, when the ice had either wholly volatilized or had become detached from the bulb of the thermometer. The ice attached to the latter did not partially fuse at the commencement of the heating because, the heat reaching

2.



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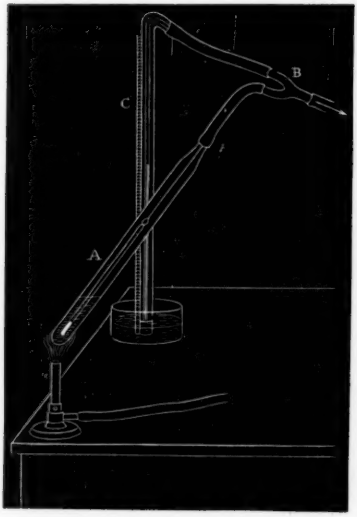


the outer surface of the ice first, evaporation could take place from a free surface and the vapor not become imprisoned, as was the case with the ice attached to the sides of the tube.

These experiments were repeated many times and always with the same result, except in one case in which the heat

applied had been very strong indeed and the ice attached to the sides of the tube fused completely. On removing the lamp, however, for a few seconds the water froze again, notwithstanding that the portion of the glass in contact with it was so hot that it could not be touched without burning the hand.

The chief conditions necessary for success appear to be—(1) That the condenser (A, fig. 1) is sufficiently large to *maintain* a good vacuum. In the present case the capacity was about three-quarters of a liter; (2) That the ice is not in too great mass, but arranged in thin layers. Further, in the case where the heat is applied to the under surface of the layers of ice, the latter must be sufficiently thin to allow of a vent-hole being formed for the escape of the steam coming from below, otherwise fusion occurs. When the heat is applied to the free surface of the ice, the layers may be much thicker.

Mercuric Chloride,

m. p.=288°, re-solidifies at 270–275°, b. p.=303°.

About 40 grs. of pure mercuric chloride were placed in the tube (A, fig. 3), and a thermometer arranged with its bulb imbedded in the salt. The drawn-out end of the tube was connected by a stout india-rubber tubing with one branch of the three-wayed tube B, while the other was attached to the manometer C. B was connected with a Sprengel pump, fitted with an arrangement for regulating the pressure.

When the pressure had been reduced by means of the pump to below 420^{mm}, the mercuric chloride was strongly heated by the flame of a Bunsen's burner, with the following results:

Not the slightest fusion occurred, but the salt rapidly sublimed into the cooler parts of the tube, while the unvolatilized portion of the salt shrank away from the sides of the tube and clung tenaciously in the form of a solid mass to the bulb of the thermometer, which rose considerably above 300° C., the mercury of the thermometer shooting up to the top of the stem. After slight cooling the air was let in, and under the increased pressure thus produced the salt attached to the bulb of the thermometer at once melted and began to boil, cracking the tube at the same time.

The experiment was next varied as follows:—

About the same quantity of chloride was placed in the tube A, fig. 3, as before, and heated by the full flame of a Bunsen's burner. The lamp was applied during the whole of this experiment, and the size of the flame kept constant throughout. The mercuric chloride first liquefied and then boiled at 303° under ordinary pressure, and while the salt was still boiling the pressure was gradually reduced to 420^{mm}, when the boiling point slowly fell to 275°, at which point the mercuric chloride suddenly

began to solidify, and at 270° was completely solid, the pressure then being 376^{mm}. When solidification was complete the pump was stopped working, but the heat still continued to the same extent as before. The salt then rose rapidly to temperatures above that at which a thermometer could be used, but not the least sign of fusion was observed. From the completion of the solidification to the end of the experiment the pressure remained at about 350^{mm}.

The above experiment, which was repeated three times, shows, therefore, that when the pressure is gradually reduced from the ordinary pressure of the atmosphere to 420^{mm}, and the boiling point simultaneously from 303° to 275°, the salt solidifies while it is still boiling and in contact with its own hot liquid notwithstanding that it is being strongly heated at the same time; and that, after solidification is complete at 270°, the temperature then rises far above the ordinary boiling point (303°) of the substance without producing any signs of fusion. Under ordinary circumstances, mercuric chloride melts at 288° and re-solidifies at 270°–275°, i. e., at a temperature identical with that at which it solidifies under diminished pressure, as above described.

The solid mercuric chloride obtained on solidification under the combined influence of diminished pressure, and the application of a strong heat had a peculiar appearance, quite different to that produced when the substance is allowed to solidify in the ordinary way. It appeared to consist of a mass of pearly leaflets closely packed together round the bulb of the thermometer.

Any final explanation of these phenomena is reserved until further experiments have been made.

Appendix.

Since writing the foregoing, it has been said in explanation of the phenomena therein described, that the thermometer, though embedded in the mass of ice, did not really indicate the true temperature of the latter. With the object, therefore, of proving whether the ice is hot or not, I have, at the suggestion of Professor Roscoe, made the following calorimetrical determination.

The arrangement of the apparatus was so modified, that the ice, after being strongly heated, could be suddenly dropped into a calorimeter containing a known quantity of water of known temperature. The resulting temperature, after the ice had been dropped in, was read off by a thermometer graduated so as to indicate a difference of 0°·05 C. The weight of the ice was found by re-weighing the calorimeter.

So far, I have only had the opportunity of completing the two following determinations, and in the second of these the weight of the ice could not be found, as a small quantity of water was lost out of the calorimeter, owing to a sudden jerk at the moment the ice entered it:—

(1.) Weight of water in calorimeter, including the value of the latter = 185 grms.

Weight of ice dropped in = 1·3 grms.

Temperature of calorimeter before = 13·4°
" " after = 13·6

Rise in temperature = 0·2

$M(\theta - t) + 80W = W(T - \theta)$

$\therefore (185) \times 0{\cdot}2) + (80 \times 1{\cdot}3) = 1{\cdot}3(T - 13{\cdot}6)$

$\therefore$ T = 122° C. Where T = temperature of ice.

(2.) Weight of water in calorimeter, &c. = 185 grms.

Temperature of calorimeter before = 12·7°
" " after = 12·8

Rise in temperature = 0·1

On weighing the calorimeter after the experiment, the increase in weight was only 0·15 grams, but as a portion of the water had been jerked out during the operation, the true weight of the ice and therefore its temperature could not be found. But since the calorimeter had slightly risen in temperature, the ice must have been above 80° C.

From the nature of the experiment, as carried out on the present scale, the weight of the ice which can be dropped into the calorimeter is only small, and therefore the rise in temperature is but slight. But since a fall in temperature of a much larger amount ought to have been obtained had the ice been at 0°, it is considered that the above experiments are conclusive. Great care was taken, in order to obtain correct temperatures in the calorimeter. The latter was inclosed in several casings, and the water was allowed to stand in it for several hours before the experiment, so that it might first attain the temperature of the room, while the time which elapsed between the readings of the thermometer before and after the ice was dropped in would not be more than from 10 to 15 seconds.

In the course of the next few weeks I intend to make one or two more determinations, and if possible, on a larger scale.

ART. L.—*Note on the Geology of the Peace River Region;* by GEORGE MERCER DAWSON, Assistant Director Geological Survey of Canada.

THE first definite knowledge of the geological features of the Peace River basin was obtained in 1875. In that year Mr. Selwyn, Director of the Geological Survey of Canada, setting out from McLeod's Lake, in British Columbia, descended the Parsnip and Peace Rivers to the confluence of the Smoky with the latter, returning by the same route. The geographical and geological notes published in the report of the expedition have constituted the basis of subsequent work. In 1879 the Canadian government decided to ascertain more completely than had previously been possible, the character of the Peace and Pine Passes through the Rocky Mountains as prospective railway routes, and the economic value, agriculturally and geologically, of the Peace River basin. The writer represented the geological survey on the expedition of that year, and the information now obtained, with that previously alluded to, enables a clear general idea of the geological features of the district to be formed. The geology of this region is of interest as representing the farthest northern portion of the Mesozoic interior continental basin yet known with any precision, the country examined lying chiefly between the 54th and 57th parallels of north latitude. The general geological result of the exploration is the preliminary examination of a section extending from the Pacific Coast to Edmonton, on the Saskatchewan, including the entire Cordillera belt, between the parallels above mentioned, with a length in all of about 700 miles. The remarks here following refer to the eastern portion of this section only.

The Rocky Mountain Range about the sources of the Peace is narrow and comparatively low, the higher peaks seldom exceeding 6,000 feet. It is chiefly composed of limestones in massive beds, which are underlain by saccharoidal quartzites, and overlain on the west by micaceous and plumbaginous schists. In some of the limestone beds, fossils of Devonian age have been found, the most abundant form being *Atrypa reticularis*, a shell widely distributed over the Mackenzie River district farther to the north. The beds of the mountains have general westerly dips, and overturned folds probably occur. On the east side of the range, on both Peace and Pine Rivers, hard dark calcareous beds are found holding *Monotis subcircularis*, a form characteristic of the "Alpine Trias" of Nevada and California, and found also in several places on the British Columbian Coast.

To the east of these beds of the mountains, and resting quite unconformably on them, are the Cretaceous rocks, which, between the mountains and the eastern outcrop of the Devonian rocks on the Lower Peace, occupy a basin with a width of nearly 350 miles, implying a Cretaceous sea of that width.

The Rocky Mountains have here formed a shore-line in Cretaceous times,—though probably not a continuous one—and the Cretaceous rocks along their eastern base are almost entirely sandstones and conglomerates, the constituent fragments of which can be traced to the cherts and quartzites accompanying the limestones of the mountains. The mountains are bordered to the east by foot-hills, in which, on the upper part of Pine River, for a distance of about fifteen miles from the older rocks, the Cretaceous sandstones are folded and disturbed. The disturbance, however, gradually diminishes on receding from the mountains, and the beds at length become flat, or are affected by very slight and broad undulations only. Slaty materials increase in importance eastward, and the Cretaceous series eventually resolves itself into the following subdivisions—clearly shown on Smoky River—which in the annexed table are placed opposite their supposed equivalents in Meek and Hayden's and the Southern Rocky Mountain sections.

Upper, or Wapiti River Sandstones,	Fox Hill (and Laramie?)	
Upper, or Smoky River Shales,	Pierre.	Colorado Group.
Lower, or Dunvegan Sandstones,	Niobrara.	
Lower, or Ft. St. John Shales,	Benton.	
	Dakota.	

The correlation, as above shown, is based partly on paleontological evidence, and partly on lithological resemblance. That the upper Shales represent the Pierre group is quite clear, as a large number of characteristic fossils of this stage have been obtained on Smoky River. No fossils have been found in the overlying sub-division. The fossils of the lower Sandstones are peculiar, consisting chiefly of fresh-water and estuarine mollusks and land plants. In the lower Shales the most characteristic form is a large Ammonite resembling *Ammonites* (*Prionocyclus*) *Woolgari*, but, according to Mr. Whiteaves, specifically distinct. The Peace River country being so remote from the typical region of the Cretaceous sub-divisions, it is not intended to insist on their precise synchronism with the groups here mentioned, but merely to point out a probable general equivalency. No beds so low as the Dakota group

have yet been found in this region, though it is probable that they occur on the Peace below the confluence of the Smoky.

The lithological resemblance of the shales of the Upper and Lower sub-divisions to those of the Pierre and Benton subdivisions is exceedingly close. It is probable that these mark periods of general submergence, when sediment-bearing currents passed freely through the interior continental valley. Elevation is known to have been in progress during the Niobrara period in the Rocky Mountain region to the south, and in the Dunvegan Sandstones, we may see an indication of the elevation of land surfaces to the north and west, which interrupted these currents and allowed the undisturbed deposition of the calcareous Niobrara beds of the south and east of the interior continental region.

The fossils of the Lower or Dunvegan sandstones are of especial interest, giving us a number of fresh-water mollusks and land-plants of a stage of the Cretaceous, previously almost unrepresented in these respects. The fresh-water mollusks closely resemble those of the Laramie group, and the plants, while showing a close analogy with those of the Dakota group, help to fill a gap in time between these and those of the Vancouver (Chico) Cretaceous, and the Laramie and Fort Union. They include species of *Cycadites*, *Magnolia*, *Protophyllum*, *Sequoia*, *Glyptostrobus gracillimus*, etc., which will be described in the forthcoming Report of Progress of the Geological Survey.

In 1872, Professor Meek described a series of beds at Coalville, Utah, which appear to have been formed at the edge of the Cretaceous sea, at the mouth of a small river, and hold fresh-water mollusks. The fossils from these beds represent a stage somewhat higher in the Cretaceous than those of the Dunvegan rocks, but closely resemble them and those of the overlying Laramie series. *Brachydontes multilinigera* of the Coalville section, is found in several places in the Dunvegan beds. After remarking on the peculiar character of this fauna, Meek writes:* "Here we have, from beds certainly overlaid by one thousand feet of strata containing Cretaceous types of fossils, a little group of forms, presenting such modern affinities that, if placed before any paleontologist unacquainted with the facts, they would be at once referred to the Tertiary."

In the Peace River district we find, instead of a merely local intercalation of this kind, a widely-extended series of beds of Cretaceous age, persistently holding fresh-water and estuarine types of mollusks and land plants.

The chief evidence going to prove the Tertiary age of the Laramie and Fort Union beds, after that afforded by the plants,

* U. S. Geol. Survey of Territories, 1872, p. 435.

has been found in the Tertiary aspect of the mollusks, most of which are fresh or brackish-water forms. Hitherto little has been known of the fresh-water fauna of the undoubted Cretataceous, but if this should prove to have, as now appears probable, a "Tertiary" aspect throughout, it will tend to break down the molluscan evidence of the Tertiary age of the Laramie, and unite this formation still more closely with the underlying beds.

Montreal, March 1, 1881.

ART. LI.—*On the Shadows obtained during the Glow Discharge;* by H. B. FINE and W. F. MAGIE.

IT is well known that a body interposed between the poles of a Holtz machine causes a so-called *electrical shadow* to appear upon the positive glow. We believe, however, that the fact that a similar shadow can be obtained upon the negative glow has not yet been published. These appearances seemed of some importance as offering a further proof of the essential similarity of the positive and negative discharges. The following points with reference to them may be of some interest.

The glow was best obtained on either electrode when the other terminated in a point, the positive glow showing to better advantage on the smaller, and the negative glow on the larger of the two balls usually employed as terminals. Whenever either the positive or negative glow was established, a well defined shadow was cast upon it by any body, preferably a non-conductor, interposed between the electrodes. By careful manipulation, the smaller ball being used as positive, the larger as negative terminal, both glows were obtained at the same time, and shadows could be made to appear upon them simultaneously. The observations of Professor Wright* on the positive shadow were verified and found to hold for the negative also; and, in fact, all the phenomena obtainable with the one were likewise characteristic of the other.

These shadows, in general, whether positive or negative, represent closely the outline of the interposed object. If, however, the lines of electrical action be deflected by the presence of a conductor, the form of the shadow is altered. We could not effect any such alteration by merely blowing across the field.

The size of the shadow varies with the tension on the electrode, becoming smaller as this is heightened. This fact is

* This Journal, II, xlix, 381.

easily illustrated by touching the electrode upon which the glow appears, and then removing the hand. The shadow, which at first covers almost the whole surface of the ball, rapidly diminishes as the tension rises. The size of the shadow further depends on the distance of the interposed object from the glowing electrode, though the relations of size and distance could not be very definitely determined. When the point and ball were used as terminals, the shadow appeared greatest when the interposed object was near either electrode and least when it was half way between them. When the two balls were used and both glows established at once, and generally when the discharge opposite the glow came from several points, the shadow decreased regularly as the interposed object was further removed.

It would not be proper for us to omit mention of the fact that Professor C. A. Young has since informed us that he noticed the existence of the negative shadow several years ago.

J. C. Green School of Science, Princeton, N. J.

ART. LII. — *Note on a New Form of Galvanometer for Powerful Currents;* by Professor C. F. BRACKETT, College of New Jersey.

THE very powerful currents produced by large dynamo-machines are not easily estimated by the appliances usually found in the physical laboratory.

The various forms of the electro-dynamometer, the cosine galvanometer and some other special forms of apparatus may of course be employed with satisfactory results. None of these instruments being in the collection at Princeton, it was determined to construct a galvanometer which should obey the law of tangents and yet not be so large as to be unwieldy. In order to this, recourse was had to the differential principle. The construction is as follows:

Two stout hoops of copper or brass of different diameters are very exactly turned in the lathe. They are then each cut open at one point and joined to each other concentrically, by soldering, with hard solder, between the ends on one side of the cut, a piece of metal having the same cross section as that of the hoops, and of suitable length. At several other points are inserted between the hoops pieces of hard rubber of proper thickness, which serve to keep them truly concentric.

The three ends of the system thus arranged and set upright on a proper base board are joined to binding screws.

It will be seen that the differential action on a needle placed at the center, or on the axis of the hoops passing through their

center, depends on the different distances of two equal and opposite currents. It is evident also that the instrument may be used as a simple tangent galvanometer.

Thus if we call the free ends of the hoops A and B respectively, and the point of juncture C, by joining up a circuit through A and B we get the differential action; but by joining up through C and A or B, the action is that of a simple tangent galvanometer. If r and r' represent the radii of the outer and inner hoops respectively, the ordinary formula becomes

$$I = \frac{r\,r'}{2\pi(r-r')} \times H \tan d$$

when the instrument is used differentially.

An instrument has been constructed at the J. C. Green School of Science for its Physical Laboratory of dimensions as follows:

Diameter of outer hoop.....	10·9 cm
Diameter of inner hoop.....	9·96cm
Width of each hoop.....	2·3 cm
Thickness of each hoop...	0·35cm

The theoretical constant of this instrument agrees very closely with that ascertained experimentally by means of the voltameter. The needle which is usually suspended in the center of the hoops, may, if desired, in order to measure exceedingly powerful currents, be moved along their axis to any required distance on one side. The constant is, in that case, easily found by an obvious modification of the formula.

Princeton, March 10, 1881.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Chlorhydrates of Metallic Chlorides.*—Compounds formed by the union of hydrochloric acid with metallic chlorides have been described, but they have been very imperfectly studied. Since these bodies appear to perform an important part in certain reactions, Berthelot has investigated them, both chemically and thermally. By the prolonged action of hydrochloric acid gas upon a solution of cadmium chloride saturated in the cold, a well defined and crystallized body $CdCl_2(HCl)_2(H_2O)_7$ is obtained, which fumes in the air and loses hydrochloric acid; but since cadmium chloride absorbs this gas even when fused the dissociation is not complete at a red heat. Thermally $CdCl_2 + (HCl)_2$ gas $+(H_2O)_7$ liquid, evolves $+40{\cdot}2$ calories; with solid water, $+30$ calories. Bromhydrate of bromide of cadmium and the iodhydrate of iodide of cadmium were also obtained in beautiful

crystals. Iodhydrate of lead iodide, and iodhydrate of silver iodide, the former $PbI_2(HI)_2(H_2O)_5$ and the latter $(AgI,HI)_5(H_2O)_7$, were prepared by dissolving the iodides in hydriodic acid. The first of these evolves 23·3 calories, the second 21·6 calories. The actual existence of such bodies is therefore beyond question. By reason of the heat of their formation, and their conditions of dissociation, they determine many reactions hitherto inexplicable; such for example as the decomposition of mercurous chloride by hydrochloric acid: $Hg_2Cl_2+nHCl=HgCl_2nHCl+Hg$. Now it appears that $Hg_2Cl_2=HgCl_2$ solid $+Hg$ liquid absorbs 19 calories; and hence the reaction results from the formation of a chlorhydrate of mercuric chloride which evolves more heat than 19 calories. The production of these compounds also plays an important part in the reduction of metallic chlorides by hydrogen. —*Bull. Soc. Ch.*, II, xxxv, 291, March, 1881. G. F. B.

2. *On a Characteristic color-reaction of the Sulph-hydrates.*— Claesson has confirmed the reaction observed by Andreasch, i. e., the production of a deep red color when ferric chloride is added to a solution of a thioglycolate, and has considerably extended it, by showing that it belongs not to thioglycolic acid alone but is a general reaction characterizing all sulphhydrates both inorganic and organic, including the well known sulphocyanate test. Sulphides and disulphides give no color with ferric chloride. The following sulphhydrates react with it to produce the colors given: sulphhydrate of methyl, of ethyl, of amyl, of benzene, of toluene, toluene disulphhydrate, and thiacetic acid give a dark red-brown color; thioglycolic and thiolactic acids a dark red-violet; sulphocyanates a dark red; hyposulphites the same; alkali and alkali-earth sulphhydrates a green color. The test is applied by dissolving the substance in water or alcohol, adding some ammonia, and then a few drops of a very dilute ferric chloride solution. The color appears immediately, but owing to reduction of the iron, it disappears in a short time.—*Ber. Berl. Chem. Ges.*, xiv, 411, March, 1881. G. F. B.

3. *On the Composition of Sodium Hyposulphite.**—Bernthsen some time ago proposed a quantitative method for the determination of hyposulphite of sodium founded on the decolorization of an ammoniacal solution of copper sulphate, indigo-carmine being used as an indicator. He has now examined this body anew and has sought to determine its composition by a method different from that used by Schützenberger. To the solution obtained by the action of zinc on hydro-sodium sulphite, chloride of barium was added to precipitate the sulphurous and sulphuric acids. The filtered solution contained sodium, barium and zinc hyposulphites, with only a trace of thiosulphate. By converting the hyposulphite into sulphate by means of iodine, determining carefully both the iodine used and the sulphuric acid formed, it appeared that each sulphur atom in the hyposulphite required three

* The author, following Roscoe, uses the name "hyposulphite" for the hydrosulphite of Schützenberger, and gives the name "thiosulphate" to the old hyposulphite.

iodine atoms to convert it into sulphuric acid. Hence the state of oxidation in the hyposulphite is represented by the formula S_2O_3. So from the cuprous salt resulting from the reduction of ammoniacal cupric sulphate by which the hyposulphite is converted into sulphite, it appears that to every two atoms of sulphur in the hyposulphite one atom of oxygen is necessary: $S_2O_3+O=(SO_3)_2$. Estimating now the ratio of bases to sulphur in the solution, there appeared one of base to one of sulphur. The simplest formula would therefore be $NaSO_3$. But from the dibasic character of the sulphur acids this should probably be doubled $Na_2S_2O_4$. Its formation is given in the equation:

$$Zn+(HNaSO_3)_4=ZnSO_3+Na_2SO_3+Na_2S_2O_4+(H_2O)_2$$

—*Ber. Berl. Chem. Ges.*, xiv, 438, March, 1881. G. F. B.

4. *On the Ignition of Combustibles by Nitric Acid.*—The impression is a very general one that nitric acid, even of 1·52 gravity, will not inflame ordinary combustibles. KRAUT, however, having made some experiments on the subject, gives a method by which sawdust, straw, hay, tow or shavings may be easily ignited by means of nitric acid. A wooden box 25^{cm} square and 40^{cm} high is filled to a height of 15 to 20^{cm} with one of the above mentioned combustibles. On this a beaker or flask is placed containing 25 to 100^{cm} of nitric acid of at least 1·5 sp. gr. and the box is then filled with the material. The glass is now broken and a wooden cover placed on the box. In one or two minutes, vapors are visible. A thick white smoke appears a little later and then the odor of the burning material is observed. If after five or ten minutes the box be opened, the interior is filled with a burning mass which bursts into flame on the access of air.—*Ber. Berl. Chem. Ges.*, xiv, 301, Feb. 1881. G. F. B.

5. *On Pernitric Oxide.*—In experimenting upon the silent electrical discharge and the effects produced by it, BERTHELOT observed that a mixture of oxygen and nitrogen tetroxide became decolorized under its action; but that the resulting compound was slowly decomposed, reproducing the orange vapor. That the new compound of nitrogen and oxygen thus obtained was not nitric oxide (N_2O_5) was proved by exposing it to a freezing mixture; no crystals were formed as would have been the case had it been N_2O_5. At St. Claire Deville's suggestion Hautefeuille and Chappuis have repeated Berthelot's experiment and have examined the product with the spectroscope. They find in the decolorized mixture characteristic bands, which seems to confirm the supposed existence of pernitric oxide.—*Ann. Chim. Phys.*, V, xxii, 432, March 1881. G. F. B.

6. *On the Atomic Weight of Platinum.*—The atomic weight generally assumed for platinum varies between 196 and 198 and rests upon the determinations of Berzelius (1826) and Andrews (1852). The former decomposed potassium-platinum chloride by igniting it in a stream of hydrogen. From the ratio of Pt to KCl, the at. wt. 196·705 was obtained; from the amount of Pt in the salt, 196·98; and from the loss of weight by reduc-

tion, 197·234. Andrews digested the potassium-platinum chloride with zinc; weighed the platinum precipitated and determined the chlorine in the solution. He obtained 197·88 as a mean. SEUBERT, observing that in the periodic systems of classification of Lothar Meyer and Mendelejeff platinum comes before gold while the above atomic weight puts it after this metal, has undertaken a revision of the atomic weight of platinum. The pure metal was prepared by Schneider's method, which depends on the fact that when warmed with excess of sodium hydrate, the tetrachlorides of all the platinum metals except platinum itself, are converted into lower chlorides not precipitable by alkali chlorides. The solution in aqua regia was therefore evaporated to expel excess of nitric acid, mixed with sodium hydrate solution and boiled for a long time. On addition of HCl, an olive green precipitate of iridium sesquichloride fell down, and the filtered solution treated with a hot solution of ammonium chloride, gave a heavy precipitate of ammonium-platinum chloride. By ignition, this precipitate left 127 grams of a bright gray platinum sponge, which was dissolved in aqua regia and the solution evaporated and then diluted to 400^{cc}. Pure potassium chloride was prepared from pure crystallized hydro-potassium carbonate by solution in hydrochloric acid; recrystallization and fusion. The ammonium chloride was purified by the method of Stas. For preparing the double salts four successive operations were used: In the first, the concentrated solution of the alkali chloride was poured into the moderately dilute Pt solution containing the calculated quantity of metal, and the precipitate thoroughly washed and dried, at 150° to 160° for the potassium, and 100° to 110° for the ammonia salt. The double salts were reduced by hydrogen and the platinum washed. In the second, this platinum sponge was dissolved in dilute aqua regia, evaporated with HCl, dissolved in acidulated water, concentrated to crystallization while a current of chlorine was passed through it, the drained crystals dissolved in acidulated water, diluted to a definite volume and divided into halves. Each was diluted to a liter, cooled and poured into a liter of alkali chloride solution also cooled, containing 50 grams of the ammonium and 60 of the potassium salt. Both salts were recrystallized and reduced by hydrogen. In the third, the sponge was dissolved in HCl, chlorine being continuously passed into the solution, the platinum precipitated as double salt, recrystallized and ignited. In the fourth, the solutions were more dilute and the alkali chlorides were in excess. The final yield of double chlorides was analyzed by heating the salt placed in a boat of porcelain, in a current of hydrogen. The final values obtained were (A) for the ammonium salt (*a*) by the platinum determination 194·68495, 194·03928, 194·66507, 195·03374, in four experiments; (*b*) by chlorine estimation 195·33013; (B) for the potassium salt (*a*) by platinum 194·39190; (*b*) Pt: KCl, 194·49368; (*c*) Pt: Cl_4 194·63088; or as a mean 194·62003. After introducing corrections and reducing to a vacuum the mean value obtained is 194·34050; which the

author regards as the atomic weight of Platinum.—*Liebig's Ann.*, ccvii, 1, Feb., 1881. G. F. B.

7. *On a Compound formed by Camphor with Alcohol.*—The production of a liquid compound by the union of camphor with hydrochloric, nitric or sulphurous acid, is well known. BALLO has observed the same phenomenon with alcohol. When an excess of camphor is heated with alcohol of a certain concentration, the portion remaining undissolved fuses and collects above or below the solution, according to the gravity of the alcohol. With alcohol of 0·8844 the camphor solution boils at 83·7° and the camphor fuses above this point; the fused camphor is heavier than the solution. At 0·8927, the solution boils at 85°, and the camphor fuses at 85°. At 0·9055, the boiling point is 82° and the fusing point 71°, the specific gravity of the solution and the melted camphor being nearly equal. At 0·9277, the boiling point is 85° and the fusing point 69°, the melted camphor now floating on the solution. At 0·9598 the boiling point is 86°–87°, the fusing point 66°–67°. At 0·9763, both points are at 89°. Hence it appears that the limits between which camphor fuses in common alcohol are comprised between 36 and 65 per cent of absolute alcohol. There appears to be more than one definite compound of camphor and alcohol formed, since the fusing point varies from 66° to 71°. After cooling, the camphor which has been thus liquefied is scarcely to be distinguished from ordinary camphor. Dried between folds of paper it contains only traces of alcohol.—*Ber. Berl. Chem. Ges.*, xiv, 334, Feb., 1881. G. F. B.

8. *On the Naturally-occurring Mydriatic Alkaloids.*—LADENBURG has given in a complete form the results of his researches upon the naturally-occurring mydriatic alkaloids. These bodies are three in number: 1st, Atropine $C_{17}H_{23}NO_3$, occurring in *Atropa belladonna*, and *Datura stramonium*, and splitting into tropic acid $C_9H_{10}O_3$, and tropine $C_8H_{15}NO$. 2d, Hyoscyamine, $C_{17}H_{23}NO_3$, occurring in *Atropa belladonna*, *Datura stramonium*, *Hyocyamus niger*, and *Duboisia myoporoides*, and splitting also into tropic acid $C_9H_{10}O_3$ and tropine $C_8H_{15}NO$. 3d, Hyoscin, $C_{17}H_{23}NO_3$, occurring in *Hyoscyamus niger*, and splitting into tropic acid $C_9H_{10}O_3$ and pseudo-tropine $C_8H_{15}NO$. It appears then that the mydriatic alkaloids occurring in nature are only three in number and that they are all isomeric with one another.—*Liebig's Ann.*, ccvi, 274, Feb., 1881. G. F. B.

9. *On the Synthesis of Tropic acid.*—SPIEGEL has effected a new synthesis of tropic acid by acting on acetophenone with hydrocyanic acid, producing the cyanhydrin of acetophenone. This heated to 130° with strong hydrochloric acid gives chlorhydratropic acid. By the action of soda on this for a short time atropic acid is produced, and for a longer time tropic acid. To this the author assigns the formula $C_6H_5\begin{cases}CH_2\\COH\\COOH.\end{cases}$—*Ber. Berl. Chem. Ges.*, xiv, 235, Feb., 1881. G. F. B.

10. *Photographs of Nebulæ.*—M. J. Janssen calls attention to the effect of short and long exposures upon the negatives which are obtained. Photographs of the same nebula will not agree unless the same conditions of exposure are narrowly observed. In proof of this the photographs of the solar corona taken at Siam in the eclipse of 1875 are referred to: the nebulosity, so to speak, of the corona gave different impressions upon sensitive plates which were exposed during times expressed by the numbers 1, 2, 4, 8: and it must be inferred that the changes in the height of the corona are to be attributed to the times of exposure, instead of to actual variations in the extent of the phenomenon. It is then indispensable that the photographs of nebulæ should be accompanied by some evidence of the conditions under which they are taken, in order that subsequent observers may study the changes in the nebula. M. Janssen proposes to take the photograph of the image of a star, or nebula, a little out of focus. In this case the photograph is a little circle of sensibly uniform opacity, and one can compare the opacity of the photographs of different stars and connect the degrees of opacity with the photometric power.—*Comptes Rendus*, Feb. 7, 1881. J. T.

11. *New form of Mercury-pump.*—H. Ernst Bessel-Hagen describes a modification of Töpler's quicksilver pump (Töpler, Dingler polyt. I, clxiii, p. 426, 1862). The pump is much simpler than the Gimingham pump which was used by Crookes and is not so liable to break. It allows the vessel which is to be exhausted to be connected to the pump without the intervention of stop cocks or metallic joints. Nothing but a continuous glass tube connecting with the pump by a mercury packing is employed. The importance of heating the tube which is to be exhausted in order to drive off the layer of air which adheres to the sides of the vessel is insisted upon. H. Hagen has obtained an exhaustion of $0{\cdot}000012^{mm}$, while Crookes has obtained only $0{\cdot}000046^{mm}$. Besides heating the vacuum tube to expel the air rom its sides, H. Hagen passed electric discharges through the tube and found these discharges efficacious in dislodging the air from the sides of the tube. He also disproves the statement that a vacuum has been obtained through which electrical discharges will not pass. At the pressure of $0{\cdot}000012^{mm}$ electrical discharges through the vacuum tube were made apparent by loud sparks in the outer circuit and by a phosphoresent glow within the tube. The influence of mercury vapor upon Crookes' phenomena is also shown. The endeavor to detect the passage of aqueous vapor through the sides of the vacuum tube by spectrum analysis gave a negative result.—*Annalen der Physik und Chemie*, No. 3, 1881. J. T.

12. *Absorption of the Sun's rays by the Carbonic Acid of the Atmosphere.*—H. Ernst Lecher, by means of observations with a thermo-electrical apparatus in connection with observations with a pyrheliometer, arrives at the conclusion that the amount of carbonic acid which has been proved to exist in the air is sufficient

to cause the absorption which has generally been attributed to aqueous vapor alone. He believes also that his method is better adapted for obtaining the amount of carbonic acid in different layers of the atmosphere than the chemical methods hitherto adopted.—*Annalen der Physik und Chemie*, No. 3, 1881.

J. T.

13. *Conversion of Radiant Energy into Sonorous Vibrations.*—Mr. WILLIAM HENRY PREECE, in a paper read at the Royal Society, March 10th, gives the details of numerous experiments upon the effect of intermittent beams of light in producing sonorous vibrations. It was found that their vibrations were not produced by the disc which received the intermittent beam, but were due to the motion of the air contained in the hearing tube, for the sounds were louder without the disc than with it. These sounds were increased when the sides of the tube were covered with lampblack, and were cut off by an athermanous diaphragm. A spiral of fine platinum wire was enclosed in a blackened tube and an intermittent current was sent through it. The sounds produced by this apparatus were excellent and proved that the sound vibrations were due to the motion of the air. A microphone was then substituted for the interrupter, and it was found that the apparatus served as a telephone receiver and articulate speech was reproduced.—*Nature*, March 24, 1881. J. T.

14. *On the Tidal Friction of a Planet attended by several Satellites, and on the Evolution of the Solar System;* by G. H. DARWIN, F.R.S. (Abstract of a paper read before the Royal Society, Jan. 20, 1881.)—The first part of the paper contains the investigation of the changes produced by tidal friction in a system consisting of a planet with any number of satellites revolving round it in circular orbits. The planet's equator and the satellites' orbits are all supposed to be in one plane. The planet is formed of homogeneous viscous fluid, but a large part of the results, due to the particular sort of tidal friction which arises in this special case, would be equally true under a more general hypothesis as to the nature of the planet. The mutual perturbations of the satellites are neglected, so that only the rotation of the planet and the distances of the satellites have to be considered.

It is then proved that if E be the whole energy, both kinetic and potential, of the system, and if ξ be a function of the distance of any one of the satellites from the planet (which function, when the mass of the satellite is small compared with that of the planet, is the $\frac{1}{2}$ power of the distance), the equation expressive of the rate of change of ξ is

$$\frac{d\xi}{dt} = -A\frac{\delta E}{\delta \xi}$$

where t is the time, A a certain constant, and δ expresses partial differentiation.

A similar equation applies to each satellite, and the whole of

the equations form a system of simultaneous differential equations which have to be solved in order to trace the changes in the system of satellites.

Expressions are also found for the rotation of the planet, and for the energy E, in terms of the resultant moment of momentum of the system and of the ξ's.

It is then shown how these equations may be solved by series, proceeding by powers of the time. As, however, the series are not rapidly convergent, they are not appropriate for tracing extensive changes of configuration.

The case where there are only two satellites is then considered in detail, and it is shown that, if a surface be constructed, the points on which have E and the two ξ's as their three rectangular coördinates (E being drawn vertically upward and the ξ's being horizontal), then the solution of the problem is expressed by the statement that the point, representing on the surface the configuration of the system, travels down the steepest path.

The contour-lines on this "surface of energy" are illustrated by figures, and the graphical solution found therefrom is interpreted and discussed.

The second part of the paper contains a discussion of the part played by tidal friction in the evolution of the solar system.

It is proved that the rate of expansion of the planetary orbits which arises from the friction of the tides raised by the planets in the sun must be exceedingly small compared with that which arises from the friction of the tides raised by the sun in the planets. Thus the investigation in the first part of the paper, where the satellites are treated as particles, is not applicable to the solar system.

Although the problem of finding the changes in a system, formed by a rigid or perfectly fluid sun attended by tidally disturbed planets, is easy of solution, yet it seemed inexpedient to attempt a numerical solution which should be applicable to the solar system.

It appeared, however, likely that a knowledge of certain numerical values would throw light on the question. Accordingly the moments of momentum of the orbital motion of the planets round the sun, of the sun's rotation round his axis, of the orbital motion of the satellites round their planets, and of the rotation of the planets about their axes are evaluated with such degree of accuracy as the data permit.

From a comparison between the orbital momenta of the planets and their rotational momenta, it is concluded that tidal friction can scarcely sensibly have enlarged the planetary orbits since the planets had a separate existence.

By parallel reasoning (although the argument has much less force) it also seemed improbable that the orbits of the satellites of Mars, Jupiter, and Saturn have undergone very large extensions since the satellites had separate existences, and it seemed nearly certain that they cannot be traced back to an origin almost

in contact with the present surfaces of their planets, as was shown in previous papers to be probably the case with the moon and earth.

The numerical values spoken of above exhibit a very striking difference between the condition of the earth and the moon and that of these other planets, and it may therefore be admitted that their modes of evolution have also differed considerably.

The part played by tidal friction in the evolution of planetary masses is then discussed.

A numerical comparison is made of the relative efficiency of solar tidal friction in reducing the rotational momentum and the rotation of the several planets. It is found that the efficiency as regards the rotation is nearly the same for Mars and for the earth, notwithstanding the greater distance of the former from the earth. This point is important with reference to the rapid revolution of the inner satellite of Mars, and confirms the explanation of this fact, which has been offered in a previous paper.

The numbers expressive of the relative efficiency of solar tidal friction are of course very much smaller for the more remote planets than for the nearer ones, but they must not be supposed to represent the total amount of rotation destroyed by solar tidal friction, because the exterior planets must be presumed to have existed much longer than the interior ones. Nevertheless the disproportion between the numbers is so great that it must be held that the influence of solar tidal friction on Jupiter and Saturn has been considerably less than on the nearer planets.

The manner in which tidal friction and the contraction of a planetary mass would work together is then considered, and it is found to be probable that tidal friction was a more important cause of change when the masses were less condensed than it is at present; thus the present rate of action of solar tidal friction is not to be taken as a measure of what has existed in all past time.

This discussion leads the author to assign a cause for the observed distribution of satellites in the solar system. For if, as the nebular hypothesis supposes, satellites are formed when instability is produced by the acceleration of rotation accompanying contraction, then the epochs of instability would recur more rarely if tidal friction were operative than without it; and if tidal friction were sufficiently powerful, an epoch of instability would never occur.

The efficiency of solar tidal friction diminishes as we recede from the sun, and therefore planets near the sun should have no satellites, and the number of satellites should increase for the remoter planets. This is the observed condition of the solar system.

This theoretical view is also shown to explain how the earth and moon came to differ from the other planets in such a manner as to permit tidal friction to be the principal feature in their evolution, while its effects are less striking in the other planets.

Among other points discussed are the comparative speeds of rotation of the several planets, and the probable effects of the genesis of a satellite on the course of change afterwards followed by a planet.

The paper ends with a review of the solar system, in which it is shown that the tidal hypothesis is a means of coördinating many apparently disconnected phenomena, besides giving a history of the earth and moon since the origin of the latter.

These investigations afford no grounds for the rejection of the nebular hypothesis, but while they present evidence in favor of the main outlines of that theory, they introduce modifications of considerable importance. Tidal friction is a cause of change of which Laplace's theory took no account, and although the activity of that cause is to be regarded as mainly belonging to a later period than the events described in the nebular hypothesis, yet its influence has been of great, and in one instance of even paramount importance, in determining the present condition of the planets and of their satellites.

15. *Sight: An Exposition of the Principles of Monocular and Binocular Vision;* by JOSEPH LECONTE, LL.D. 275 pp. 8vo. New York, 1881. (D. Appleton & Co. International Scientific Series.)—Professor LeConte has given a popular and readable, and at the same time scientific, exposition of the subject of vision. Two-thirds of the volume are devoted to binocular vision, a subject to which the author has contributed much by his own researches (see numerous articles in this Journal). The development of this subject is a feature of the volume, and gives it especial value, although it may perhaps seem to some that other topics of no less interest are sacrificed to it.

II. GEOLOGY AND MINERALOGY.

1. *Jurassic and underlying strata in the Section of the Alps along the St. Gothard Tunnel.*—A brief notice of this section by M. Renevier, is given in vol. xvi of this Journal (1878). During the past year an account of the rocks has been published by M. Stapff, as an Appendix to the Report of the Swiss Federal Council. A few facts are here cited from Professor Favre's Review of Swiss Geology, for 1880, published in the Geneva Archives des Sciences, Feb., 1881.

The section is 14,920 meters long. The northern, 2010 meters, are through the mass of the Finsteraarhorn; from 2010 to 4325 meters through the fold of Ursern; from 4325 to 11,742 meters through the mass of St. Gothard; and the remaining 3178 meters through the fold of Tessin. The rock of the mass of the Finsteraarhorn is a gneissoid granite (made of quartz, orthoclase, some triclinic feldspar and black and white mica), with gneiss between 1100 and 1525 meters. There are many faults, especially in the region of the gray gneiss. In the fold of Ursern, made up of several secondary folds, the center consists of cipolin or calcareous

beds containing traces of fossils, probably of Jurassic age, and accompanying it are black schists of the Lias and older formations. More to the south there is another corresponding fold, in which occur schists, apparently the equivalent of the cipolin beds, flanked, like them, with black schists. These beds are enclosed by the gneiss of Ursern, having some quartzose and green beds, constituting the borders, so that the whole has the form of a ω.

In the Gothard mass, which next follows, there is gneiss varying to mica schist and to granite, with some serpentine (between 4870 and 5310 meters), and, subordinate to the gneiss, hornblendic beds. The rocks are closely related to those of the fold of Ursern, passing into them by an insensible gradation. The fan-like position of the beds of Gothard is much more distinct to the south than on the northern side. These Gothard rocks are sedimentary metamorphic terranes, joining without interruption to the most recent beds of the folds of Ursern on the north and of Tessin on the south.

In the fold of Tessin, the rock, to within ninety meters of the south end, is mica schist, often garnetiferous; in part hornblendic; partly calcareous mica schist; and then there are fifty-three feet of dolomite. These rocks have close analogies to those of the Ursern fold, the cipolins of Altekirch corresponding to the dolomite of Tessin, the sericite schists to the gray garnetiferous mica schist, and so on. The group then in the valley of Tessin represents also altered sedimentary strata from the Jurassic to the Carboniferous. The beds plunge under Gothard with a marked curve, the dip being greater at the surface than in the tunnel.

Thus, the author observes, the mass of Gothard consists of a series of metamorphic sediments, and the folds of Ursern and Tessin, on the opposite sides, correspond to one another. The gneissoid granite of the Finsteraarhorn is the oldest of the series, and a break exists between it and the Ursern fold.

The serpentine of the Gothard mass is considered by M. Stapff as formed by the alteration of olivine, some grains of which still remain. M. Cossa has shown that part of the rock, though of a kind capable of changing to serpentine, is not true serpentine, but consists of talc, pyroxene (not lamellar) and olivine, with the pyroxene sometimes predominating. Gümbel has found fragments of *Crinoids* in the limestones of Andermatt, confirming the view of M. Stapff as to the origin of the limestones.

2. *The great fault in the Alps after the Carboniferous era.*— According to M. Lory (Observations sur la structure des Alpes, in C. R. du Congr. Internationale de Geol. of 1878), the dislocation which raised the crystalline schists in the zone of Mount Blanc, between the Bernese Alps on the east and Maritime Alps on the southwest, took place after the deposition of the Carboniferous beds which are conformable to these schists, and before the Triassic era, the Mesozoic beds being laid down unconformably on the schists, and sometimes now overlying them in horizontal

masses (Aiguilles Rouges, Oisans). There were also other movements after the deposit of the Mesozoic strata, but of less extent.

3. *Radiolarians (Polycystines), making for the most part the Jasper beds of Tuscany.*—Dr. D. PANTANELLI has published a paper on the Tuscan jaspers in the Transactions of the R. Accademia dei Lincei (Rome), 1880, giving the results of the microscopic study of the Tuscan beds of jaspers in the Eocene, Cretaceous and the Upper Lias. The author gives a double quarto plate of figures of the fossils, and shows that the beds are marine deposits, and were probably formed at some considerable depth, since Radiolarians are most abundant in the deeper waters, the number being proportionately largest, according to observations hitherto made, between 5000 and 10,000 feet.

4. *Fossil Sponge-Spicules from the Upper Chalk, found in the interior of a single flint-stone from Horstead in Norfolk;* by GEORGE JENNINGS HINDE, F.G.S. 84 pp. 8vo, with 5 plates. Inaugural Dissertation. Munich, 1880.—The material examined was from an interior closed cavity of a mass of flint and resembled fine meal. The author describes, from it, 160 forms of spicules, which he refers to 38 species and 32 genera of Sponges, 14 of the species belonging to the Lithistids and Hexactinellids. Besides the spicules of sponges, the cavity afforded remains of Foraminifers, Ostracoids, Echinoderms, Annelids, Cirripeds, Bryozoans, Brachiopods, Lamellibranchs and Fishes, the first two kinds, with the sponges, being far the most abundant. The abundance of the sponge spicules sustains the author's conclusion that flint nodules of the Chalk have resulted from the aggregation of the siliceous spicules or skeletons of the sea-bottom sponges, as the chalk from an aggregation of the shells of foraminifers, ostracoids and other calcareous secretions of the same seas. The author remarks that only two or three Radiolarians are yet known from the Chalk formation. The plates are crowded with excellent figures of the spicules.

5. *Vertebrates of the Permian of Texas.*—Professor E. D. COPE has a second paper on this subject in the Proceedings of the American Philosophical Society, xix, 38 (1880). Professor Cope describes in this memoir two species of *Theropleura* Cope (near the Rhynchocephalia), one of *Dimetrodon* Cope, one of *Diadectes*, two of *Helodectes* Cope, defines anew the genera of Ganocephala, *Eryops* Cope and *Trimerorhachis* Cope, and describes one fish of the tribe Crossopterygia, *Ectosteorhachis nitidus* Cope.

6. *Report of the Professor of Agriculture of the University of California*, 1880. 108 pp. 8vo. Sacramento, 1881.—Professor E. W. HILGARD presents, in his report, besides other discussions of importance, some interesting facts with regard to the reclamation of alkali lands. As ordinary surface irrigation tends to concentrate the alkali at the surface—"the more water evaporates from the surface within a season, the more alkali salts will be drawn to the surface." The chief remedy proposed is underdraining, which "may so far lower the water-table from which the

saline matters are derived, and may so far favor the washing out of the salts during the rainy season, that the latter will thereafter fail to reach the surface so as to accumulate to an injurious extent with reasonable tillage." In his illustrations of the subject analyses are given of the waters of Kern and Tulare lakes, and of some rivers of California. In that of Kern Lake, March, 1880, the total residue obtained was 211·50 grains per gallon (about 26 times more than in an average river water), which consisted of Carb. soda 64·37, common salt, glauber salt, etc. 115·41, carb. Ca, Mg and silica 9·29, vegetable matter 22·43. The water from the middle of Tulare Lake, at surface, afforded 81·95 for the total residue, consisting of Carb. soda 35·30, common salt, glauber salt, etc. 35·96, carb. Ca and Mg, and silica 5·37, vegetable matter 5·32.

Water of the Cañon of Kern River afforded 9·49 of total residue; but the proportion between the sodium carbonate and the other salts is almost exactly that in the water of Tulare Lake, or 1 to 22; so that, if 22 gallons were boiled down to 1, the water would have the same alkali in quantity and quality as that of the lake; and if further reduced to 3½ pints, it would have about the composition of that of Kern Lake. Professor Hilgard remarks as follows respecting the use of the Kern River waters in irrigation:

"Those using its waters should keep in mind that their evaporation adds annually to the alkali in the soil;" and that "tillage after irrigation, the planting of deep-rooted crops instead of grain, and the use of gypsum as a neutralizer of the worst ingredient—the carbonate of soda—are the measures that suggest themselves as the most feasible; while subirrigation, and especially the leaching out of the alkali from time to time by long-continued flooding, and underdrainage are more radical remedies for future use." After a further discussion of the facts he adds: "There are, probably, few river-waters in the world of such composition, or natural purity, that continued irrigation without correlative underdrainage can be practiced without in the end causing an injurious accumulation of soluble salts in the soil. In India, according to the testimony of Professor George Davidson, the evil effects of such practice have become painfully apparent, and, to such an extent, that after the expenditure of enormous sums for bringing the water upon the fields, the government now finds itself face to face with the costly problem of its economical removal by drainage, so as to relieve the soil of its accumulated alkali which has rendered it unfit for cultivation. An early attention to this matter, with such foresight as will prevent the occurrence of similar difficulties cannot be too earnestly recommended to all interested in the irrigated lands of California."

7. *Biennial Report of the State Geologist of the State of Colorado*, for the term ending December 31, 1880. 75 pp. 8vo. Denver, 1881.—Professor J. Alden Smith, appointed geologist of Colorado in 1872, gives in this report a general description of the gold and silver mines of the State, with remarks on the other

sources of mineral and agricultural wealth. He gives also a very full catalogue, arranged alphabetically, of the mineral species found in the State. This is a revision and extension of a catalogue published by him in 1870, and it includes notices of the recent work by Dr. Genth, Dr. Lœw and others on Colorado minerals. To complete the long list of Colorado species the work by Allen and Comstock on bastnäsite, and the new species tysonite, should properly be mentioned.

8. *Grundlinien der Geologie von Bosnien-Hercegovina.*—Erläuterungen zur geologischen Uebersichtskarte dieser Länder, von Dr. Ed. v. Mojsisovics, Dr. E. Tietze and Dr. A. Bittner, Mit Beiträgen von Dr. M. Neumayr und C. v. John und einem Vorworte von Fr. v. Hauer. 322 pp. 8vo, with a colored geological chart and three lithographic tables. Vienna, 1880.—This work treats of the stratified formations of the region, from the Paleozoic to the Quaternary, the local geology of the different parts, the crystalline rocks, and closes with a chapter on the "Tertiary Inland Mollusks," by Dr. Neumayr.

9. *Journal of the Cincinnati Society of Natural History*, for Jan., 1881.—This number of the Journal has a descriptive bibliographic paper on the N. A. Tertiary, by S. A. Miller; descriptions of new Tineina, by V. T. Chambers; papers on the Geographical distribution of certain N. A. fresh-water mollusks and the probable causes of their variation, and on new Upper Subcarboniferous Crinoids, by A. G. Wetherby, besides other papers. In Mr. Miller's paper, the earliest paper referred to on Martha's Vineyard Tertiary, in vol. vii, 1824, is stated to be by Professor Silliman. In the title of this paper no name of author is given, but the index inserts the article under the name of Edward Hitchcock. The same volume contains, on pp. 31–43, an article entitled "Geological essay on the Tertiary formations in America," by John Finch (read before the Acad. Nat. Sci. of Philadelphia, in 1823), which well deserves to be noticed: it recognizes as Tertiary the deposits of the Atlantic border from Gay Head and New York to the Gulf of Mexico, and gives many important details.

10. *Geological Reports recently issued.* (Received too late for notice in this place.)

Geological Survey of Pennsylvania.—(1) The Geology of the Oil Regions of Warren, Venango, Clarion and Butler Counties, by John F. Carll. No. III. 482 pp. 8vo., with 23 plates and an atlas of 22 sheets of maps, oil-well sections, and working drawings of oil-well rig and tools. Harrisburg, 1880. (2) Report of Progress of Armstrong County, by W. G. Platt. No. H^5. 338 pp. 8vo, with a colored map of the county. Harrisburg, 1880. (3) The Geology of Clinton County, Part II, containing a special study of the Carboniferous and Devonian strata along the west branch of the Susquehanna River, by H. Martin Chance, with a description of the Renovo Coal Basin by C. A. Ashburner, and notes on the Tangascootack Coal Basin in Centre and Clinton Counties, by F. Platt. 174 pp. 8vo, with a colored map, sheet of sections, topographical map of the Renovo Basin, 6 plates and 21 sections in the text. Harrisburg, 1880. The volume by L. Lesquereux on Coal plants, briefly noticed on page 329, has also been issued.

Geological Survey of New Jersey: Annual Report for the year 1880, by the State Geologist, Prof. G. H. Cook. 220 pp. 8vo, with a colored map.

State of Indiana.—Report of the Department of Statistics and Geology, 1880, by JOHN COLLETT. 544 pp. 8vo, with plates.

Geological Survey of Canada.—Report of the Geology of Southern New Brunswick, 1878–79, by Prof. L. W. BAILEY, G. F. MATTHEWS, and R. W. ELLS. 261 pp. 8vo, with a large geological map and 6 plates of sections. Montreal, 1880. (Dawson Brothers.)

11. *Lazulite from Canada.*—The occurrence of lazulite in the District of Keewatin, near the mouth of the Churchill River, is described by C. Hoffmann (Geology of Canada, Report of Progress for 1878–9). The mineral occurs massive in narrow veins in quartz. It has a deep azure blue color; its specific gravity is 3·0445. An analysis afforded the following results (after the deduction of 3·81 p. c. silica, as impurity):

P_2O_5	Al_2O_3	FeO	MgO	CaO	H_2O
46·39	29·14	2·09	13·84	2·83	6·47=100·76

The Chemical Contributions to the Geology of Canada (25 pp.) by Mr. Hoffmann, from which the above analysis is quoted, contain also an analysis of cyanite from North Thompson River, British Columbia, others of graphite, kaolin, alunogen, also analyses of various natural waters, coals, iron, copper and manganese ores, gold and silver assays, etc.

12. *The Minerals and Mineral Localities of North Carolina;* being chapter I of the second volume of the Geology of North Carolina. 122 pp. 8vo. Raleigh, 1881.—This volume opens with a general statement by the State Geologist, Prof. Kerr, and following this is the extended report by Dr. F. A. Genth. A description is given of each of the species discovered in the State, embracing not only whatever has been previously published, but also numerous new analyses, mostly by Dr. Genth or his assistants; and many facts made known by the recent explorations of Prof. J. T. Humphreys, Mr. J. A. D. Stephenson, Mr. W. E. Hidden, and others. The list of species is a long one (178) and includes, more especially from the mica mines in the western part of the State, many very rare and interesting minerals, among which may be mentioned the samarskite and related species, as also the uranium minerals. A full synopsis of minerals and localities by counties will be found of value, especially by collectors. To the body of the report Mr. Hidden adds several pages in which he describes the discoveries recently made by him (see this Journ., Feb., 1881, p. 159); he figures a series of highly modified and interesting quartz crystals, and also several crystals of beryl, one of them showing the planes *I*, *i*-2, *O*, 1, 2, 2-2, 3-$\frac{3}{2}$, 4-$\frac{4}{3}$.

13. *Durability of Building Stones.*—Dr. HIRAM A. CUTTING, of Vermont, has made examinations as to the degree of heat sufficient to cause the destruction of different building stones and has extended his experiments to 22 kinds of granite, 23 of sandstone, 7 of limestone, 7 of marble, 3 of conglomerate, 1 of slate, 1 of soapstone, and 1 of artificial stone. Under the application of the heat, the granite (1) began to yield at a temperature between 700° and 800° F.; (2) became cracked between 800° F. and 900° F.; (3) became generally cracked between 800 and 950° F.

and (4) was made worthless by or before reaching a temperature of 1000° F.

The following table contains these results under the headings (1), (2), (3), (4), and those also for the other kinds of stones.

	(1)	(2)	(3)	(4)
Granites	700°– 800°	800°– 900°	800°– 950°	at or below 1000°
Sandstones	800°– 900°	850°–1000°	900°–1000°	1000°–1200°
Massive limestones	850°– 950°	900°–1000°	900°–1100°	mostly 1200°
Marbles	900°–1000°	950°–1000°	1000°–1200°	1200°
Conglomerates	600°– 700°	700°– 800°	800°– 900°	900°–1000°

The granites had a specific gravity between 2·600 and 2·727, excepting one from Stanstead, Canada, of 2·833; and immersion in water added to their weight, through absorption, from 1-280th of their weight to 1-818th. In the case of sandstones, sp. gr.= 2·168 to 2·661, but mostly under 2·400; and the absorption was 1-17th to 1-80th excepting two giving 1-240th (a freestone from Nova Scotia), and 1-314th (the Montrose stone, Ulster Co., N. Y.) For the marble, sp. gr.=2·666 to 2·848, and the absorption 1-300th to 1-380th; for the more solid of the pure massive limestones, sp. gr.=2·478 to 2·706, and absorption 1-280th to 1-480th.

The least absorbent of the granites (its ratio of absorption 1-818th) was one of the most destructible by heat, and the most absorbent (1-280th) was equally destructible. The limestones and marbles are stated to change to quicklime at about 1200° F.

14. *Brief notices of some recently described minerals.*—Begeerite. Occurs massive and in small isometric crystals, showing octahedral and dodecahedral planes. Specific gravity 7·273. Luster metallic, on the crystals brilliant. Color light to dark-gray. An analysis gave (after deducting quartz) S 14·97, Bi 20·59, Pb 64·23, Cu 1·70=101·49. This corresponds nearly to the formula $Pb_5Bi_2S_9$ or $6PbS+Bi_2S_3$. Found at the Baltic Lode, near Grant P. O., Park Co., Colorado. Named after Mr. H. Begeer of Denver. Described by Dr. G. König.—*Amer. Chem. Journ.*, vol. ii, No. 6.

Eleonorite. Occurs in small crystals belonging to the monoclinic system, resembling in habit the lazulite from Georgia; the crystals often forming drusy surfaces. Hardness 3–4. Color reddish-brown to dark hyacinth-red and streak-yellow. Luster vitreous inclining to pearly. An analysis gave P_2O_5 31·88, Fe_2O_3 51·94, H_2O 16·37=100·19, corresponding to $2Fe_2P_2O_8+H_2Fe_2O_6+5H_2O$. It is very near beraunite, if not identical with it. Found with other phosphates at the Eleonore mine near Bieber, also from Waldgirmes near Giessen. Named by Nies, and described by Streng.—*Jahrb. Min.*

Picite is a second phosphate from the same localities as *Eleonorite*. It is a glassy, apparently amorphous, mineral. Hardness 3–4. Specific gravity 2·83. Luster greasy to vitreous. Color dark-brown, streak yellow. Fracture semi-conchoidal. An analysis gave: P_2O_5 24·47, Fe_2O_3 46·50, Al_2O_3 1·00, H_2O 28·03=100. The formula corresponds to $4Fe_2P_2O_8+3H_6Fe_2O_6+27H_2O$, on the uncertain assumption that the mineral is homogeneous.—*Jahrb. Min.*, 1881, i, p. 16 *ref.* and p. 102.

NEOCYANITE. A recent sublimation product at Vesuvius, in composition essentially an anhydrous silicate of copper. It occurs in minute crystals of an azure blue color. Described by Scacchi; *Rend. Accad. Sc. Napoli*, Dec. 4, 1880.

15. *Analysis of Columbite;* by E. J. HALLOCK, Ph.D. (Communicated.)—The sample analyzed was from Middletown, Conn., and was kindly furnished to the writer by Professor Charles A. Joy. The specific gravity of the crystals freed from gangue was found to be 6·14. Two analyses afforded:—

	I.	II.
Mixed acids	82·64	82·56
Iron protoxide	11·77	12·08
Manganese protoxide	4·95	4·93
Lime	0·50	0·45
	99·86	100·02

The columbic and tantalic acids were not separated, but the specific gravity of the ignited mixed acids from No. 2 was 7·48, indicating a large proportion of tantalic acid.

Southern Medical College, Atlanta, Ga., Feb., 1881.

III. BOTANY AND ZOOLOGY.

1. *Notes on Orchideæ*, and *Notes on Cyperaceæ;* by GEORGE BENTHAM, F.R.S.—Two notable papers extracted from the (still unpublished) eighteenth volume of the Journal of the Linnean Society, and important as forerunners, being a sketch of the arrangement adopted for these orders in the forthcoming and concluding portion of the Genera Plantarum, and containing also some historical and critical details which could find no place in that condensed systematic work. It must suffice to direct attention to these papers, as we cannot now give an analysis of them. That on the *Orchideæ* is naturally far the most considerable; it occupies the pages of the volume from 281 to 360, and is a succinct exposition of a complete re-arrangement of this vast and difficult order, as to the tribes, sub-tribes, and the limitation of many genera. That on the *Cyperaceæ*, pp. 360–367, is comparatively a small affair; this family exhibiting small diversity of structure. The genera are grouped under two principal divisions (after Bœckler), each containing three tribes. The history of some of the early genera, and of the way they have been mistaken or confused, forms a curious part of Mr. Bentham's notes.

A. G.

2. *On the Germination and Histology of the Seedling of Welwitchia;* by F. ORPEN BOWER, B.A., Camb. Reprinted from the Quarterly Journal of Microscopical Science, n. ser. xxi, pp. 15–22, with two plates.—We have had the pleasure of inspecting from time to time the seedlings of *Welwitchia* which germinated early last autumn at Kew Gardens, and of which several have survived through the winter and are still thriving, although the larger portion was lost. This paper by a promising phytotomist inves-

tigates the structure and development of the mature embryo and of the seedling, and is to be followed by a research into the histology of the more advanced plant from good specimens in spirit. An important intermediate stage between these preserved young plants and the growing seedlings remains to be supplied, and may be expected from the further development of these precious living plants. Without referring here to the details of germination and of the minute anatomy, we will only refer to the two points brought to view by Mr. Bower of much interest to the morphologist. One is the production from the caulicle or hypocotyledonary stem, at the beginning of germination, of a fleshy outgrowth, which remains in the axis of the seed, enveloped by the endosperm, long after the development and liberation of the cotyledons and their elevation by the elongating growth of the caulicle. This process, of which no trace is seen before germination, either internally or externally, develops in proximity to the cotyledons, just below the constricted apex of the caulicle, and in the same plane with these, being therefore incumbent upon the back of one of them, which at one time it almost equals in length and at the base exceeds in thickness, while the apex tapers to a blunt point. The development of the caulicle, which carries up the soon foliaceous cotyledons well above ground, is almost wholly above this process, which, as already stated, remains in the seed; and the surrounding endosperm being still capable of furnishing considerable nutriment, Mr. Bower infers that the process serves as a feeder to the seedling, for the appropriation of this residual store of food. He therefore calls it "the feeder" in his description, speaking physiologically; while morphologically it is of course likened to the "peg" of germinating squashes, the very different use of which, in riving the seed-coat and freeing the cotyledons, has recently been so well described by Darwin.

The second point is that the seedling of *Welwitchia* promptly produces a two-leaved plumule, decussating with the cotyledons, and it is inferred that this pair of leaves (and not the cotyledons as had been supposed) makes the permanent foliage of this strange plant. The living seedlings give as yet no external evidence that the cotyledons are to die off; but developed young plants in spirit show apparent scars and vestiges which indicate such disappearance, and the arrangement of vascular bundles within well accords with this view. It is almost certain that the two leaves of these plants represent the permanent foliage; and the fact that they stand in the plane at right angles with that of the "peg" or process, while this in the seedling is directly under one of the cotyledons, convinces us that the permanent foliage belongs to the plumular pair of leaves. A. G.

3. *J. Freyn, of Prague, Austria*, is engaged in the preparation of a monograph upon the genus Ranunculus. He is desirous of obtaining specimens of American species and varieties, together with notes relative to their numerical distribution, their habit and habitat. For good specimens exhibiting flowers, leaves and ripe fruit, he will be glad to exchange specimens of European desiderata.

4. *Geographical distribution of certain Freshwater Mollusks of North America, and the probable causes of their variation;* by A. G. WETHERBY.—The January number of the Journal of the Cincinnati Society of Natural History contains the first part of this important memoir. A notice is deferred until the promised future paper is published.

IV. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Distribution of Time Signals.*—The American Meteorological Society has issued two circulars relating to the public distribution of time signals. The first calls attention to the convenience of having the country divided into districts which keep a time differing one hour from the times in neighboring districts, after the manner explained in the first volume of the Proceedings of the Society, and subsequently commented on in the *North American Review* for December, 1880.

The second circular includes a letter from the chief signal officer of the army, Gen. W. B. Hazen, to the president of the society, Dr. F. A. P. Barnard. In this letter the chief signal officer expresses the interest the Signal Service would naturally have in performing the important duty of dropping time balls in the various parts of the country, wherever competent local authority will furnish an accurate standard of time, and the cost of erection of the signal be assumed by those interested.

That the public is getting to be fully aware of the economic value of having large sections of country living under the same clock time has been shown by the readiness with which communities have united in such a common time when it has been proposed to them. For example, the bill establishing a common State time for Connecticut, introduced during the present session, passed both houses of the legislature without a dissenting vote: and there is no doubt that the Signal Service and the Meteorological Society will confer a greatly recognized benefit upon the public, should they be successful in introducing public time signals to the country at large. Time balls are costly, though accurate; it might be worth the while to enquire into the feasibility of also establishing time guns—which, though under some conditions less accurate than time balls, yet are generally more convenient to the public. Possibly some of the artillery of the Ordnance Department which has outlived its usefulness in warfare might be used for the purpose. We give the memorandum accompanying Gen. Hazen's letter in the foot note.

MEMORANDUM No. 1.

Conditions on which the Chief Signal Officer coöperates with others in the maintenance of a public Standard Time Ball :—

1*st.*—At any Signal Service Station already established for the benefit of commerce and agriculture, and at which two (2) or more men are necessarily stationed, the Chief Signal Officer will contribute such portion of the time of one man as will be necessary, in order to keep in perfect working order the ball, mast, elec-

trical and other apparatus at the station, and will have the ball hoisted daily at the proper time, and the electric connections properly made; provided this does not, on the average, require more of the time of the man on duty than one-half hour per day.

2*d*.—The expense of battery and battery-room, and of purchasing, installing and repairing the apparatus, as also the expense attending the astronomical determination of time and the necessary telegraphy, must be borne by other parties, and must not in any way be imposed upon the Signal Service.

3*d*.—The Chief Signal Officer will not undertake such coöperation for the benefit of special individuals, nor unless there is satisfactory evidence that the "time signals" will be in charge of such astronomers and institutions as can guarantee a high standard of accuracy, and the uniform maintenance of their part of the time service from year to year.

4*th*.—The signal, which consists in dropping the "time ball", must be given automatically by telegraphy from the Astronomical Observatory, which shall alone be responsible for the accuracy thereof.

5*th*.—The Chief Signal Officer will be pleased to publish such portions of the annual reports of the observatories in charge of time balls as relate to the accuracy of the signals.

6*th*.—Without presuming to prescribe, the Chief Signal Officer would suggest, that the interests of navigators as well as of railroad travelers, and of the community at large, will probably be best subserved by causing the respective time balls to be dropped simultaneously throughout large sections of the country, and especially at noon of the meridians of 75°, 90°, 105° or 120° of longitude west of Greenwich, in accordance with the following schedule:

Atlantic Coast	time balls all drop at noon on the				75th	meridian.
Gulf Coast	"	"	"	"	90th	"
Lake Coast	"	"	"	"	90th	"
Mississippi Valley	"	"	"	"	90th	"
Pacific Coast	"	"	"	"	120th	"

Thus, for instance, at Washington, the time ball will be dropped at exactly five hours of Greenwich mean time, which will be eight minutes earlier than Washington mean noon, and three minutes later than New York mean noon.

7*th*.—The Chief Signal Service Officer will take action in reference to time balls at any station, so soon as Chambers of Commerce, or Observatories, or other local organizations communicate their desires to him.

2. *Changes in water-level of lakes on the borders of Oregon and California.* — A letter to the editors from Mr. B. F. Dowell, of Jacksonville, Oregon, states that Goose Lake, 30 miles long and two-thirds of it in Oregon, the rest in California, was almost dry in 1853 and 1854 while in 1869 and 1870 there were ten feet of water; its depth has been increasing since 1870, and there is a probability of its discharging, as at some former time, into Pitt River. Clear Lake also, about two miles farther south, is ten feet deeper than it was in 1853–4; and Tulie Lake, in the same region (the locality of the lava beds where were the hiding places of the Modoc Indians) is 10 or 15 feet higher to-day than then.

3. *Bibliographie Astronomique.*—The second fascicule of this valuable work of Messrs. Houzeau and Lancaster has been distributed. It is devoted to Spherical Astronomy (110 columns); Theoretic astronomy (80 columns); Celestial Mechanics (100 columns); and *Astronomie Physique* (212 columns). This last subject covers not Physical Astronomy as usually understood, but cosmogony, satellites, comets, meteors, photometry, spectroscopy, etc. The references are to memoirs, not to complete works, nor

observations; these are to appear in other volumes. The work seems to be very complete, and will be invaluable to astronomers.

4. MAJOR J. W. POWELL has been appointed Director of the Geological Survey of the National Domain in place of Clarence King resigned. His various reports on the Rocky Mountain region, geological, ethnographic and economical, show that he is well fitted for the position.

5. *Report of the Superintendent of the United States Coast Survey*, showing the progress of the work for the fiscal year ending with June, 1877. 192 pp., with 25 maps. Among the Appendices are the following: Notes concerning alleged changes in the relative elevations of land and of sea, by HENRY MITCHELL; Description of an apparatus devised for observing currents in connection with the physical survey of the Mississippi River, by H. L. MARINDIN; Description of an optical densimeter for ocean water, by J. E. HILGARD; Comparison of American and British standard yards, by J. E. HILGARD; Description of an improved open vertical clamp for the telescopes of theodolites and meridian instruments, by G. DAVIDSON; Observations of the density of the waters of Chesapeake Bay and its principal estuaries, by Lieut. COLLINS; A quincuncial projection of the sphere, by C. S. PEIRCE.

Exercises in Practical Chemistry. Vol. I, Elementary Exercises, by A. S. Vernon Harcourt and H. G. Madan. Third edition, revised by H. G. Madan. 480 pp. 8vo. Oxford, 1880 (Clarendon Press).

A Memorial of Joseph Henry. 528 pp. Washington, 1880. Contents: Introduction, Proceedings in Congress relative to a public commemoration; Part I, Obsequies of Joseph Henry, pp. 7–27; Part II, Memorial services at the Capitol, pp. 37–121; Part III, Memorial Proceedings of Societies, pp. 125–475; Appendix.

A Lecture on the progress of the work of completion of the new improved bed of the Danube at Vienna, and the lessons taught thereby, together with a description of the catastrophe produced by the ice gorge of 1880, by Sir Gustave Wex. 33 pp., with five sheets of drawings. (Extract from the Journal of the Society of Austrian Engineers and Architects, No 3, 1880). Translated by Major G. Weitzel, U. S. A. Washington, 1881.

Meteorological Researches for the use of the Coast Pilot. Part II, On Cyclones, Waterspouts and Tornadoes by William Ferrel. 95 pp. 4to, with 6 plates. (U. S. Coast and Geodetic Survey, Carlile P. Patterson, Superintendant). Methods and Results. Appendix No. 10 of Coast Survey Report for 1878.

Report of the Director of the Detroit Observatory of the University of Michigan to the Board of Regents for the period beginning Oct. 1, 1879 and ending Jan. 1, 1881. 20 pp. 8vo. Ann Arbor, 1881.

Annual Report upon the Surveys of Northern and Northwestern Lakes in charge of Gen. C. B. Comstock, U. S. A., being Appendix OO of the Annual Report of the Chief of Engineers for 1880. 93 pp. 8vo, with a map and several plates.

Annual Report of the Superintendent of the Yellowstone National Park to the Secretary of the Interior for the year 1880. 64 pp. 8vo. Washington, 1881.

Notes on North American Microgasters with descriptions of a new species by C. V. Riley, Ph.D., 20 pp. From the Transactions of the Academy of Sciences of St. Louis, vol. iv, No. 2.

Parasites of the Termites, by Joseph Leidy, M.D. 25 pp. with two plates. From the Journal of the Academy of Natural Sciences of Philadelphia, vol. viii.

OBITUARY.

M. ACHILLE DELESSE, Inspector General of Mines in France, and well known for his able researches in geology and mineralogy, died at Paris near the close of March.

APPENDIX.

ART. LIII.—*Principal Characters of American Jurassic Dinosaurs;* by O. C. MARSH. Part V. With seven Plates.

IN previous articles, the writer has described the main characters of *Morosaurus*, *Apatosaurus*, *Diplodocus*, and *Atlantosaurus*, the best known genera of the *Sauropoda* hitherto found in American deposits.* The fortunate discovery of a nearly complete skeleton of *Brontosaurus* has added many new points to our knowledge of this group, and some of these are given in the present communication. A second species, equally gigantic in size, has since been found, and its distinguishing features are also here recorded.

Two new genera from the same formation are noticed, and an outline of classification of the best known American Jurassic Dinosaurs is proposed.

Brontosaurus excelsus Marsh.†

The present genus may readily be distinguished from all the other *Sauropoda* by the sacrum, which is composed of five ankylosed vertebræ, none of the other genera in this group having more than four. The sternum, moreover, consists of two separate bones, which are parial, and were united to each other on the median line apparently by cartilage only. In many other respects the genus resembles *Morosaurus*.

The present species, aside from its immense size, is distinguished by the peculiar lightness of its vertebral column, the cervical, dorsal, and sacral vertebræ all having very large cavities in their centra. The first three caudals, also, are lightened by excavations in their sides, a feature not before seen in this group, and one not shared by the other species of this genus.

* This Journal, xvi, 411, Nov., 1878, and xvii, 86, Jan., 1879.
† This Journal, xviii, 503, Dec., 1879, and xix, 395, May, 1880.

The Scapular Arch.

The scapular arch in the present species is fortunately better known than that of any other Dinosaur hitherto discovered. In Plates XII and XIII the various bones are represented separately, and in figure 1 of the latter plate they are in position. The scapula resembles in general form the corresponding bone in *Morosaurus*, but the shaft is longer, and the upper end less expanded. The coracoid, on the other hand, differs materially from that of *Morosaurus*, and approaches more nearly that of *Apatosaurus*, which is sub-quadrate in outline. In Plate XII the scapula and coracoid of the present species are placed nearly in the same plane, and the space between them probably represents about the amount of cartilage which originally separated them. Both scapulæ were found in apposition with their respective coracoids.

The two sternal bones lay side by side between the two coracoids, and in Plate XIII they are represented nearly as found. They are sub-oval in outline, concave above, and convex below. They are parial, and when in position nearly or quite meet on the median line. Each bone is considerably thickened in front, and shows a distinct facet for union with the coracoid. The posterior end is thin and irregular.

The Presacral Vertebræ.

The cervical vertebræ of the present species are quite numerous, thirteen at least belonging in this part of the column. All are strongly opisthocœlian. The anterior cervicals are very small in comparison with those near the dorsal region. From the third vertebra to the middle of the neck, the centra increase in length and especially in bulk, but the posterior cervicals gradually become shorter. In Plate XIV the sixth cervical is represented, and this is typical for the anterior half of the neck. All the anterior cervicals have coössified ribs, as in Birds. In the posterior cervicals, the ribs become free. The articular facet for the head of the rib rises gradually on the side of the centrum, the tubercular articulation remaining on the diapophysis. None of the cervicals have a neural spine. The neural canal is comparatively small. The centra of all the cervicals have deep excavations in the sides, and the transverse processes are more or less cavernous. The posterior cervicals which bear free ribs are remarkable for the great size of the zygapophyses, which are here much larger than elsewhere in the series. The anterior cervicals have several lateral cavities, while those farther back have only one large foramen in each side of the centrum, as in the dorsals.

The dorsal vertebræ of this species have short centra, more or less opisthocœlian. There is a very large cavity in each side which is separated from the one opposite by a thin vertical partition. The neural canal is much larger than in the cervicals. The anterior dorsals are distinctly opisthocœlian. The neural spine has no prominence in this region, but rises rapidly further back. In Plate XV, figures 1 and 2, a posterior dorsal is represented which shows the peculiar character of the vertebræ in this part of the series. The neural spine is greatly developed and has its summit transversely expanded. The vertebræ in this region, as in all the known *Sauropoda*, have the peculiar diplosphenal articulation. This is shown in figure 2. In the vertebra figured, at the base of the neural spine, there is a strong anterior projection, which was inserted into the cavity between and above the posterior zygapophyses of the vertebra in front. There appear to be no true lumbar vertebræ, as those near the sacrum supported free ribs of moderate size. These vertebræ have both faces of the centrum nearly flat or biconcave.*

The Sacrum.

The sacrum in the present species consists of five well coössified vertebræ, and in the type specimen the centrum of the last lumbar is firmly united with it, as shown in Plate XVI. The striking feature about this sacrum is the large general cavity it contained. This was divided in part by a median longitudinal partition, as shown in Plate XV, figure 3. This septum, however, was not continuous the whole length of the sacrum, so that the two lateral cavities were virtually one. This extended even into the lateral processes. The transverse partitions formed by the ends of the respective centra were also perforate, so that the sacrum proper was essentially a hollow cylinder. This cavernous character of the sacrum is one of the peculiar features of the suborder *Sauropoda*, and was described by the writer, when the first species of this group was discovered in this country.† The statement that any of the group have the sacrum solid, like the caudals, is evidently based on erroneous observation.

Another peculiar character of the sacrum in the present genus is its lofty neural spine. This is a thin vertical plate of bone with a thick massive summit, evidently formed by the

* Prof. Cope, mistaking the character of these vertebræ in an allied form, described them as representing a new genus, *Amphicœlias*, and even a new family, *Amphicœliidæ*. (Proc. Am. Phil. Soc., xvii, 243.) All the known *Sauropoda*, however, have similar vertebræ, with opisthocœlian centra in the cervical and anterior dorsal regions.

† This Journal, xiv, 87, July, 1877.

union of the spines of several vertebræ. In front, it shows rugosities for the ligament uniting it to the adjoining vertebra, and its posterior margin likewise indicates a similar union with the first caudal. In this genus, as in all the *Sauropoda*, each vertebra of the sacrum supports its own transverse processes. As shown in Plate XVI, the articulation for the ilium is formed by the coössification of the distal ends of the transverse processes. The neural canal is much enlarged in the sacrum, but proportionally less than in *Stegosaurus*.

The Caudal Vertebræ.

In the present species, the three vertebræ next behind the sacrum have moderate sized cavities between the base of the neural arch and the transverse processes. These shallow pockets extend into the base of the processes, but the centra proper are solid. All the other caudals have the centra, processes, and spines composed of dense bone. The fourth caudal vertebra, represented in Plate XVII, figures 1 and 2, is solid throughout, and the same is true of the chevron, figures 3 and 4. The neural spines of the anterior caudal vertebræ are elevated and massive. The summit is cruciform in outline, due to the four strong butresses which unite to form it.

The median caudals all have low weak spines, and no transverse processes. The posterior caudals are elongate, and without spines or zygapophyses.

The Pelvic Arch.

The pelvic bones in the present species are shown in Plate XVIII. The ilium represented is not perfect on its upper margin, which extended higher originally than shown in the figure. Its anterior process for the support of the pubis is much larger than the posterior one which meets the ischium. The pubis is elongate and massive. It sends down a strong wing for union with the ischium, and has in front of this the usual foramen. The distal end is expanded, and has on the inner surface a rugose facet for union with its fellow by cartilage. The ischium is more slender than the pubis, and has its lower end expanded for symphysial union with the one on the other side. This pelvis is more like that of *Atlantosaurus* than any other of the known genera of the *Sauropoda*. The three bones shown in Plate XVIII were found nearly in the position represented.

Brontosaurus amplus, sp. nov.

A second species of this genus is from the same horizon, and is represented by the greater portion of the skeleton. In size, the two were very nearly equal, but they may be distinguished readily by the vertebræ. In the present species, the dorsal vertebræ are less massive, the differences being especially noticeable in the zygapophyses. The anterior caudals, moreover, are without the cavities noticed in the type species, and are likewise proportionally longer. The single sternal bone found near its coracoid is thinner, and has its anterior border less developed than the corresponding part in *Brontosaurus excelsus*. The metacarpals of the present species are more elongate than in the other known members of the group.

Diracodon laticeps, gen. et sp. nov.

A new Jurassic Dinosaur of moderate size is indicated by various remains, among which are the two maxillary bones. These are unusually slender, and peculiar in the large number of teeth they contained. These teeth resemble in form those of *Echinodon*, Owen. They have compressed serrated crowns, sculptured on both sides. The base of the crown is expanded, and below this is a distinct neck, which will readily distinguish these teeth from any hitherto found in this country. The teeth are implanted in distinct sockets, and there were twenty-two in each maxillary. There is a foramen on the inner side, just below each tooth, and some large cavities on the outer side of each jaw. The teeth are very small.

The front of these jaws is edentulous, and this part curves inward so far that the snout must have been a broad one, almost batrachoid in form.

The following measurements indicate the size of these specimens:

Entire length of maxillary bone	170·mm
Space occupied by teeth	104·
Space occupied by eleven anterior teeth	50·
Length of anterior edentulous portion	62·
Vertical diameter of jaw, above eleventh tooth	27·

The present species was probably ten or twelve feet in length. The vertebræ referred to this animal are biconcave, and the other characters known make it probable that the genus is most nearly related to *Laosaurus*. The known remains are from the Atlantosaurus beds of Wyoming.

Hallopus, gen. nov.

The specimen described by the writer as *Nanosaurus victor*,* proves, on investigation, to be distinct from the type of the genus to which it was referred, and presents some peculiar characters. Some of these characters are as follows:

(1) There are but two vertebræ in the sacrum.
(2) The femur is shorter than the tibia.
(3) The metatarsals are one-half the length of the tibia.
(4) The calcaneum is much produced backward.

The last character has not before been seen in Dinosaurs, and indicates a foot especially adapted for leaping. The species representing this group may be called *Hallopus victor*. The animal was about as large as a fox. The geological horizon of this specimen is near the base of the Atlantosaurus beds, in Colorado, and perhaps below them.

The collection of American Jurassic Dinosaurs now in the museum of Yale College includes the remains of several hundred individuals, many of them in excellent preservation. The completeness of this series renders it valuable as a basis of classification for the known American forms, and an outline of this classification may appropriately be presented in the present article. Most of the many genera and species represented in this series can be readily grouped in five suborders, as given below, two of which have already been defined by the writer. The details of the present classification, and its application to the Dinosauria from other formations in this country, as well as to those of Europe, will be reserved for a future communication. The outline of classification now proposed is as follows:

* This Journal, xiv, 255, Sept. 1877.

Order DINOSAURIA, Owen.

(1.) Suborder SAUROPODA (Lizard foot.) Herbivorous.
Feet plantigrade, ungulate; five digits in manus and pes.
Pubes united in front by cartilage. No post-pubis.
Precaudal vertebræ hollow. Limb bones solid.

Family *Atlantosauridæ*.
Genera *Atlantosaurus*, *Apatosaurus*, *Brontosaurus*, *Diplodocus*, and *Morosaurus*.

(2.) Suborder STEGOSAURIA (Plated lizard.) Herbivorous.
Feet plantigrade, ungulate; five digits in manus and pes.
Pubes free in front. Post-pubis present.
Vertebræ and limb bones solid.

Family *Stegosauridæ*.
Genus *Stegosaurus*.

(3.) Suborder ORNITHOPODA (Bird foot.) Herbivorous.
Feet digitigrade; four functional digits in manus and three in pes.
Pubes free in front. Post-pubis present.
Vertebræ solid; limb bones hollow.

Family *Camptonotidæ*.
Genera *Camptonotus*, *Diracodon*, *Laosaurus*, and *Nanosaurus*.

(4.) Suborder THEROPODA (Beast foot.) Carnivorous.
Feet digitigrade; digits with prehensile claws.
Pubes coössified in front. Post-pubis present.
Vertebræ more or less cavernous; limb bones hollow.

Family *Allosauridæ*.
Genera *Allosaurus*, *Creosaurus*, and *Labrosaurus*.

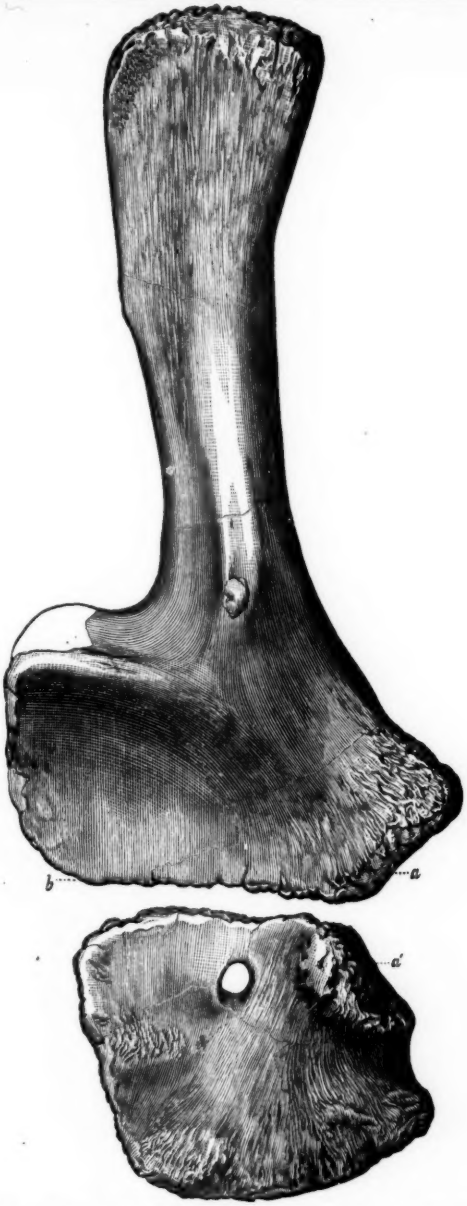
(5.) Suborder HALLOPODA (Leaping foot.) Carnivorous?
Feet digitigrade, unguiculate; three digits in pes.
Metatarsals much elongated; calcaneum much produced backward.
Two vertebræ in sacrum. Limb bones hollow.

Family *Hallopodidæ*.
Genus *Hallopus*.

DINOSAURIA?

(6.) Suborder CŒLURIA (Hollow tail.) Carnivorous?
Family *Cœluridæ*.
Genus *Cœlurus*.

Yale College, New Haven, April 15, 1881.



Left scapula and coracoid of *Brontosaurus excelsus*, Marsh; one-twelfth natural size. *a*, scapular face of glenoid cavity; *b*, rugose surface for union with coracoid; *a'*, coracoidean part of glenoid cavity.

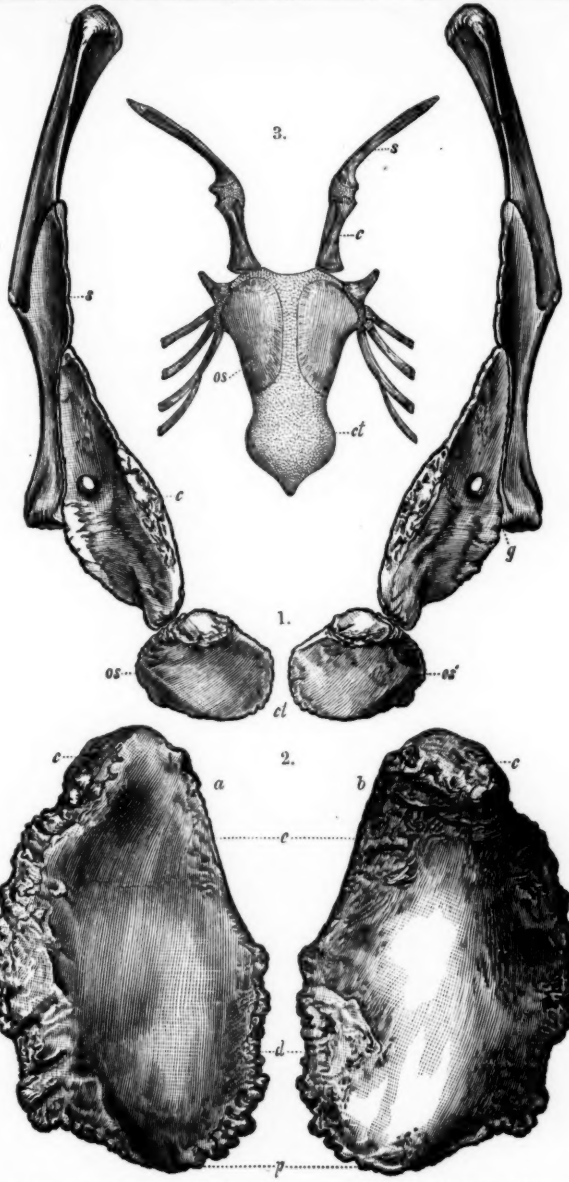


FIGURE 1.—Scapular arch of *Brontosaurus excelsus*, Marsh, front view; one-sixteenth natural size; *s*, scapula; *c*, coracoid; *g*, glenoid cavity; *os*, right sternal bone; *os'*, left sternal bone; *ct*, cartilage.

FIGURE 2.—Left sternal bone, one-eighth natural size; *a*, superior view; *b*, inferior view; *c*, face for coracoid; *d*, margin next to median line; *e*, inner front margin; *p*, posterior end.

FIGURE 3.—Scapular arch of young *Rhea Americana*, Lath; (after Parker); three-fourths natural size; seen from below. Letters as above.

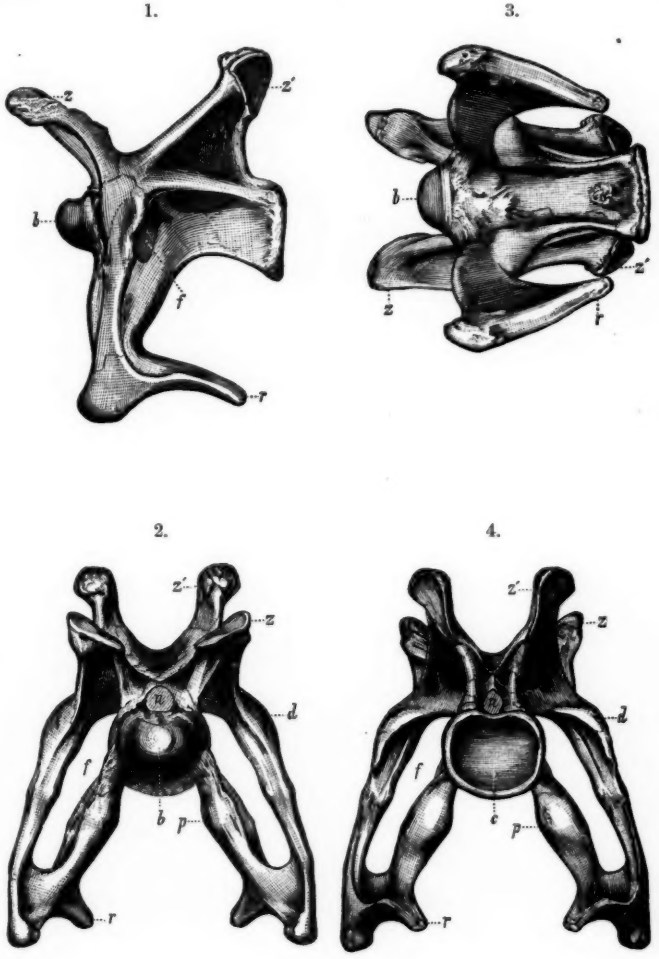
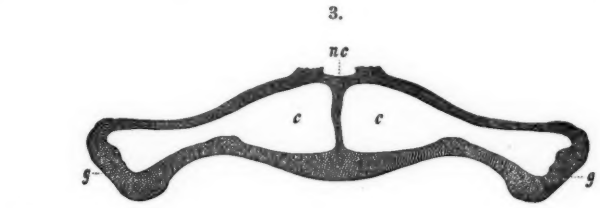


FIGURE 1.—Sixth cervical vertebra of *Brontosaurus excelsus*, Marsh, side view.
FIGURE 2.—The same vertebra, front view.
FIGURE 3.—The same, bottom view.
FIGURE 4.—The same, back view.

The signification of the letters is the same in all the figures, viz: *b*, ball; *c*, cup; *d*, diapophysis; *f*, lateral foramen; *n*, neural canal; *p*, parapophysis; *r*, cervical rib; *z*, anterior zygapophysis; *z′*, posterior zygapophysis.

All the figures are one-twelfth natural size.



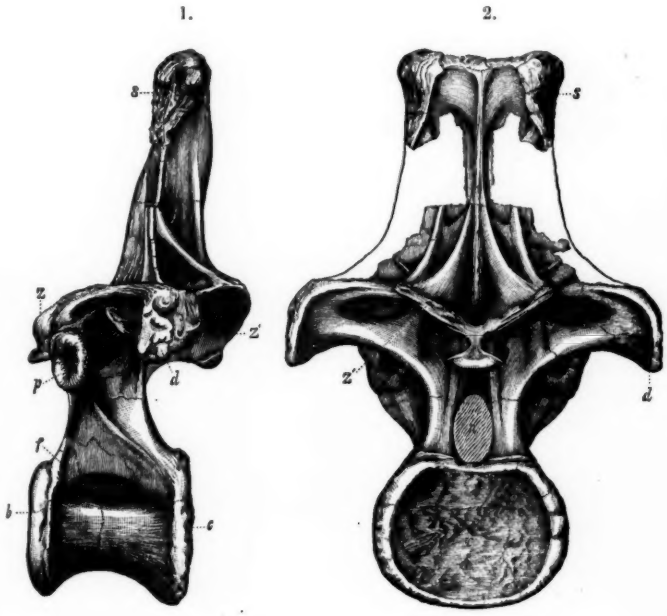
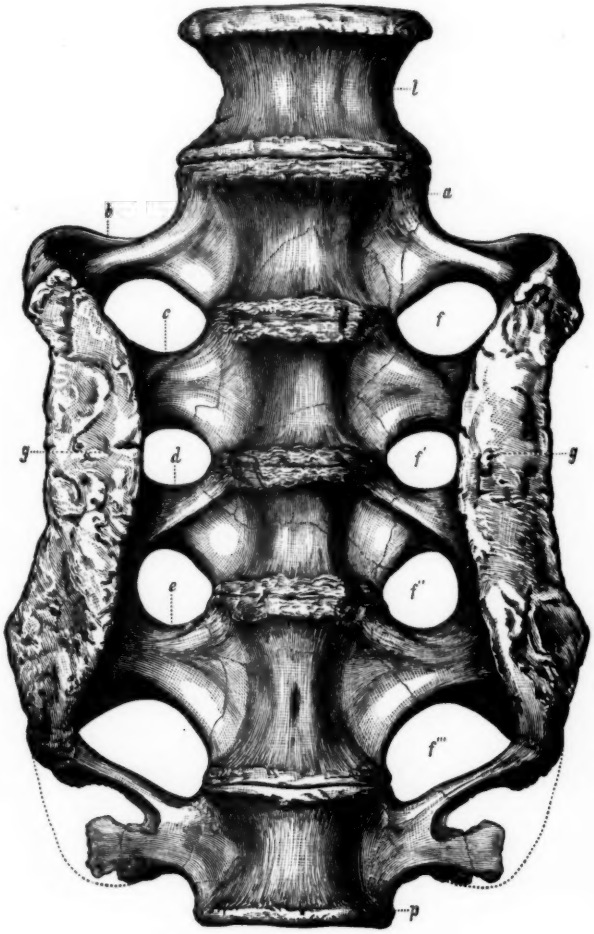


FIGURE 1.—Dorsal vertebra of *Brontosaurus excelsus*, Marsh, side view.
FIGURE 2.—The same, back view. Both one-twelfth natural size.

The signification of the letters in both figures is as follows: *b*, ball; *c*, cup; *d*, diapophysis; *f*, foramen in centrum; *n*, neural canal; *p*, parapophysis; *s*, neural spine; *z*, anterior zygapophysis; *z'*, posterior zygapophysis.

FIGURE 3.—Section through second vertebra of sacrum of *Brontosaurus excelsus*, one-tenth natural size; *c*, cavity; *g*, surface for union with ilium; *nc*, neural canal.



Sacrum of *Brontosaurus excelsus*. Marsh, seen from below; one-tenth natural size; *a*, first sacral vertebra; *b*, transverse process of first vertebra; *c*, transverse process of second vertebra; *d*, transverse process of third vertebra; *e*, transverse process of fourth vertebra; *f*, *f'*. *f''*, *f'''*, foramina between processes of sacral vertebræ; *g*, surface for union with ilium; *l*, last lumbar vertebra; *p*, last sacral vertebra.

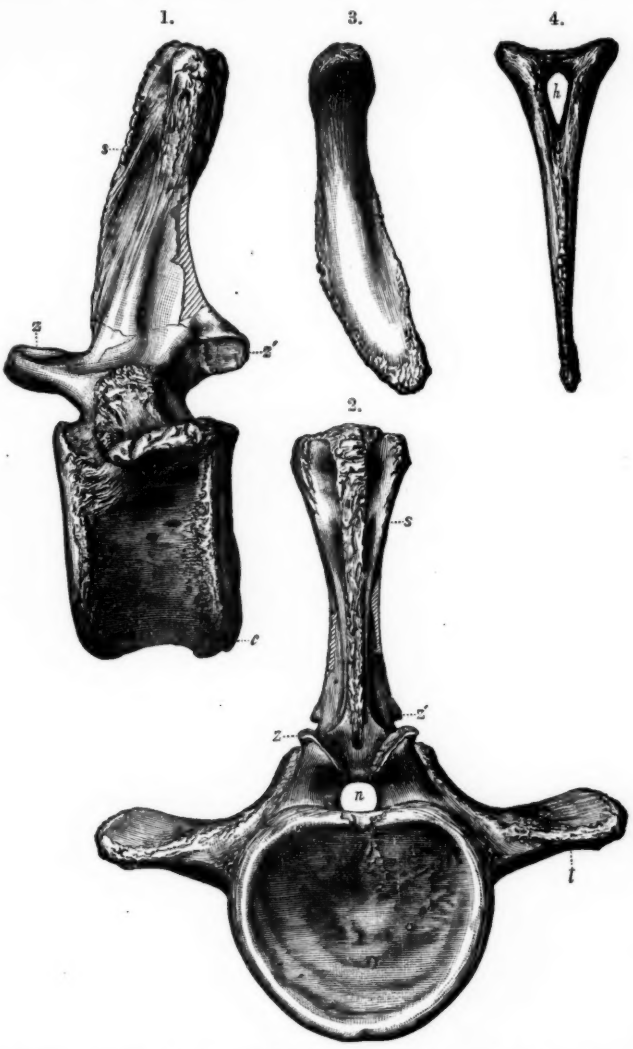


FIGURE 1.—Fourth caudal vertebra of *Brontosaurus excelsus*, Marsh, side view.

FIGURE 2.—The same, front view.

In both figures the signification of the letters is as follows: *c*, face for chevron; *n*, neural canal; *s*, neural spine; *t*, transverse process; *z*, anterior zygapophysis; *z'*, posterior zygapophysis.

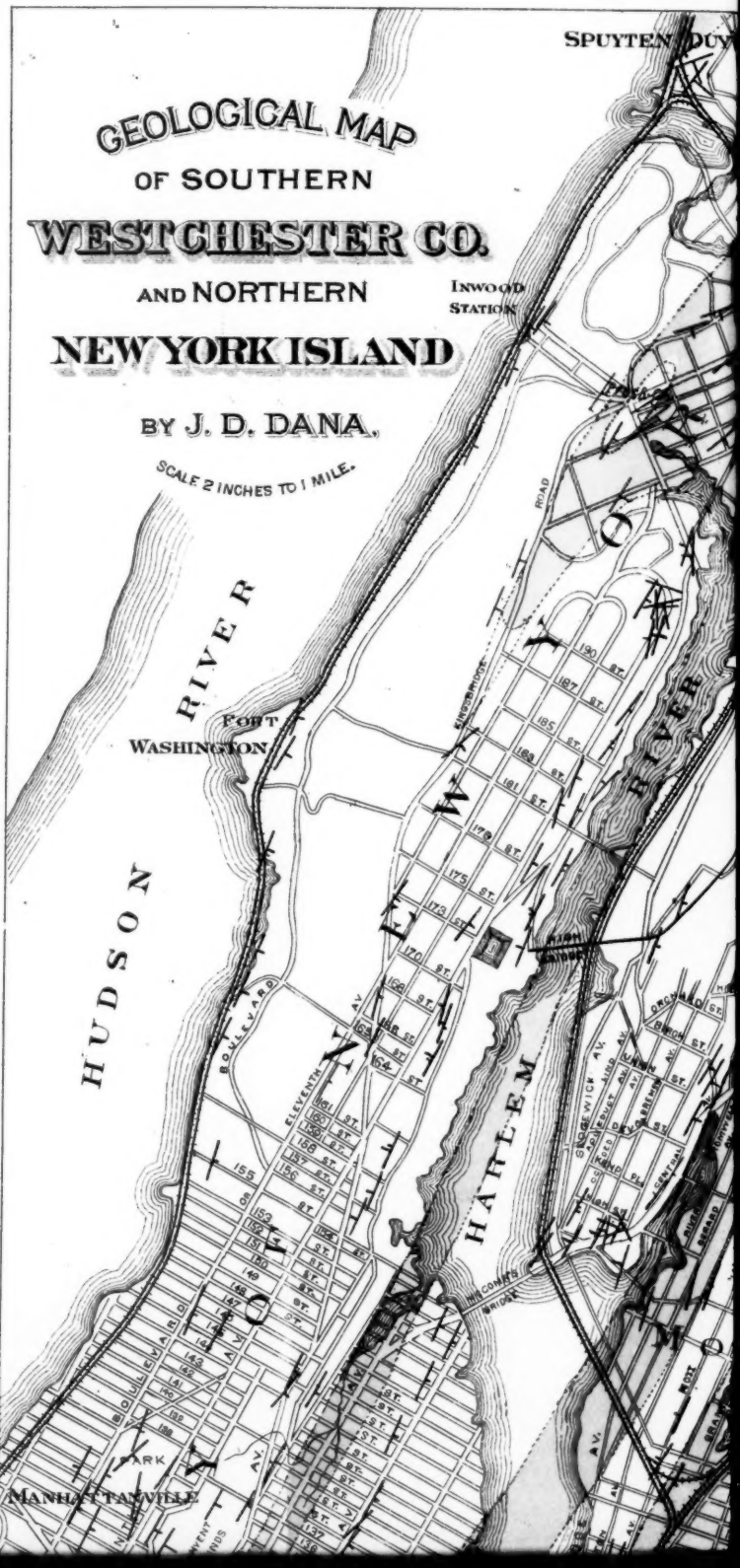
FIGURE 3.—Chevron of *Brontosaurus excelsus*, side view.

FIGURE 4.—The same, front view; *h*, hæmal canal.

All the figures are one-eighth natural size.

Pelvis of *Brontosaurus excelsus*, Marsh, seen from the left; one-sixteenth natural size; *a*, acetabulum; *f*, foramen in pubis; *il*, ilium; *is*, ischium; *p*, pubis.

In this diagram, the three pelvic bones are represented nearly in the same plane.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MORNINGSIDE AVE.
AMSTERDAM AV.
COLUMBUS AV.
BROADWAY
ST. NICHOLAS PARK
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MT. MORRIS SQUARE
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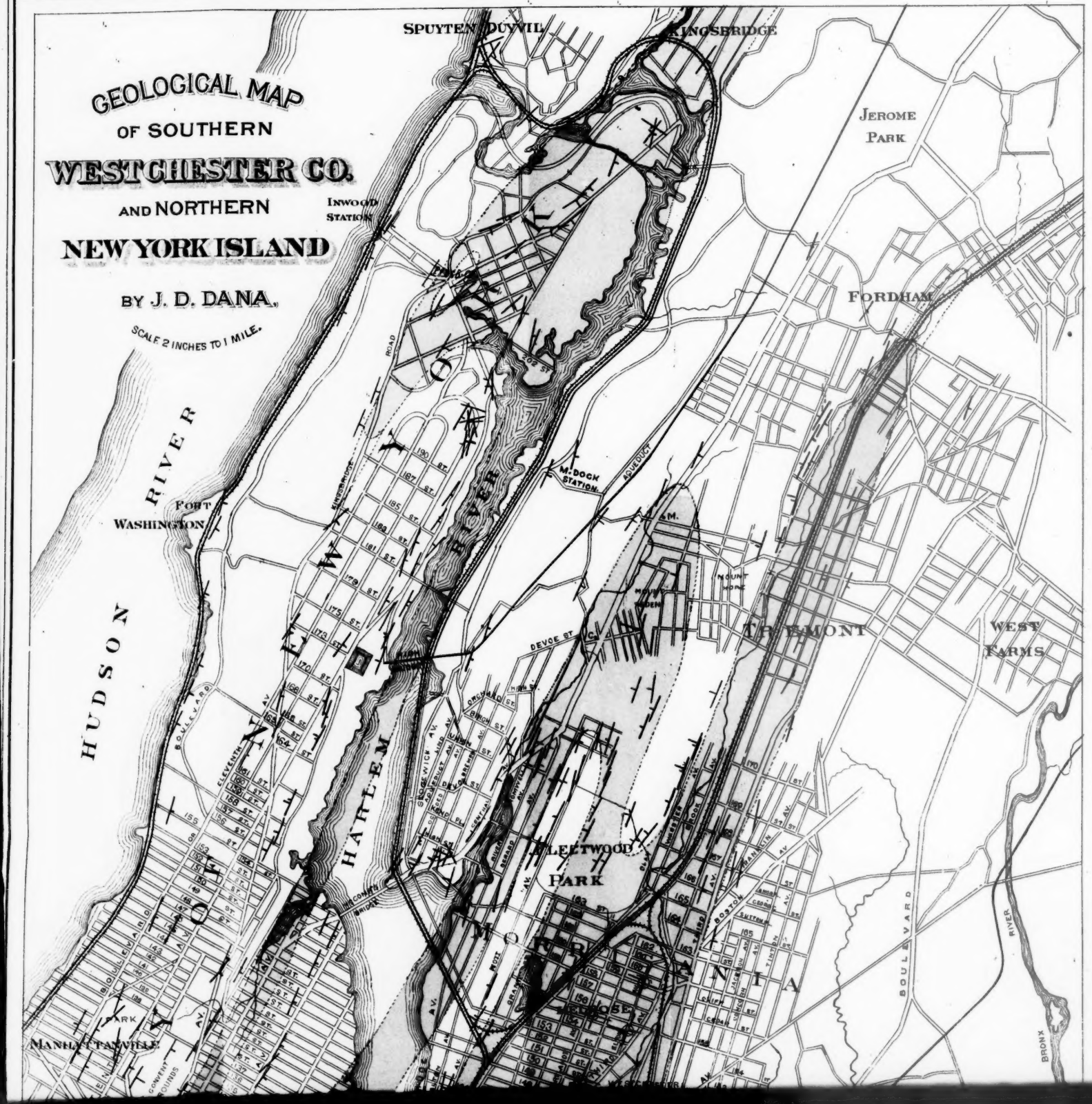
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